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The Missing Link

In a recent presidential address to the British Institution of Radio Engineers, Mr. P. Adorian made the following comments : " It is a somewhat difficult problem to ' sell ' the idea of industrial electronics to any business executive who is not himself a radio engineer or who does not employ a radio engineer. The best advice that we, as radio engineers, can give to all business executives, consulting engineers, production efficiency experts and others concerned with production, is that in whatever sphere of industry they are engaged, it would be worth their while to call in a professional radio engineer to advise them on where and how electronic methods can be applied to improve their production efficiency."

These comments reaffirm perhaps the most serious drawback to the advancement of technical progress and particularly of British industry, that is, the inability or reluctance of many practical-minded engineers to make use of the tools which scientific and engineering research lays before them. The standard of British research is among the highest in the world, and the craftsmanship of practical engineers in this country is everywhere regarded as outstanding. Since the rate of progress in industry is dependent upon the standards of both research and practice, it is imperative that a strong link be established between them, but unfortunately, this link is far too weak in this country, so much so that in the past the fruits of British research have sometimes been harvested in other countries before industry here could be forced into a realisation of their value. This position may seem odd, but it is not so difficult to understand if we examine the level of fundamental training of the personnel normally employed, for instance, in the drawing office of the medium or small-sized British firm. Apprenticeship and evening classes form the basis of their knowledge. Later on, of course, experience widens this knowledge, and they may become, and indeed many of them have become, excellent men in their own field, but does this background impart a wide enough outlook to enable them to appreciate the significance of advancements made in other fields, particularly those of scientific research ? It is only fair to say that, in view of the large volume of up-to-date knowledge they may need to acquire in order to gain this appreciation, they cannot be expected to assess the importance of such advancements for their own purposes. Mr. Adorian's words emphasise the need to call in the radio expert whenever electronic technique appears to offer a possible solution to any particular problem, but the implications are much wider.

Many methods and processes have been evolved which are not as well known as electronics. Although we may have a long way to go before most industries can claim to have fully exploited electronic methods, the position is much worse as regards other fields of applied research, which, owing to their narrower scope, have been less publicised. In such cases, the specialist is not called in, simply because his existence is known only to few. If he forces his presence upon the less enlightened, he may often find the value of his work unjustly condemned as fanciful. Yet the amount of money which could be saved by many if full use were made of the knowledge at present held by few is incalculable. Must we not, therefore, find ways and means to facilitate the dissemination and practical application of this knowledge ?

Surely, something must be done soon to bring about close co-operation between research engineers and design and production executives, so as to establish the vital link that is necessary between theory and practice.

The problem of achievement of this aim is a difficult one. Taking the long-term view, it would appear that the standard of education of the average engineer should be raised ; in other words, an improved basis of education will qualify him to appreciate the value of research and to judge the pros and cons of its practical applications. Since the problem is one calling for immediate solution, however, full use must be made of the resources at our disposal. We therefore advocate the employment of a greater number of University graduates for practical jobs, although it is realised that for the first two or three years, they are likely to be less profitable than men who have been trained on conventional lines. We have no doubt, however, that such an investment would ultimately prove to be a lucrative one for the manufacturer and, taking a broader view, would materially raise the standard and reputation of British engineering, as well as its efficiency.

U. S. A.

Oil Holes and Grooves in Plain Journal Bearings

By S. A. McKee and H. S. White. (From *Technical Report* 1449, *National Bureau of Standards*, 7 pages, 4 illustrations.)

The comparative performance of plain journal bearings having various arrangements of oil holes and grooves, operating in a four-bearing friction machine with forced-feed lubrication, was recently investigated. Part of a research programme on plain-journal bearing lubrication sponsored by the National Advisory Committee for Aeronautics has provided much useful knowledge on different methods of bearing lubrication.*

In the lubrication of the journal bearings, the method of admitting oil to the bearing constitutes an important problem in design. Fundamentally, the concept of the load-carrying film indicates that it is desirable to avoid oil holes or grooves which interfere with the normal development of hydrostatic pressure to support the load. In some bearing installations, however, it is not always possible to satisfy this requirement. For example, where loads on the bearings are fluctuating in both intensity and direction, it is sometimes impracticable to apply the oil to the unloaded side throughout the complete load cycle. In other cases, provision must be made for a continuous flow of oil to some other moving part.

The investigation covered five different arrangements for feeding oil through the bearing shell. These included one hole at the centre of the unloaded side; two holes, one each on the loaded and unloaded side; four holes, each 45 degrees from the line of the load; one axial groove at the centre of the unloaded side; and one circumferential groove. Tests were also made with three arrangements for feeding oil from the centre of a hollow shaft—that is, one and two oil holes in the shaft, and a one-oil-hole arrangement terminating in a flat that extends along the surface of the shaft for one-half the bearing length. For all these arrangements each hole or groove was in the axial centre of the bearing and was connected to the source of oil supply.

The four-bearing friction machine consists essentially of four similar test bearings enclosed in a housing and mounted on a common shaft. The complete unit of bearings and housing acts as a cradle dynamometer. Loads are applied by hydraulic jacks which form the base of the housing. The frictional torque is measured by a dynamometer scale acting through a torque arm fitted to the housing while an automatic device, provided in the hydraulic system, releases the load under the high-torque conditions that occur near bearing seizure (Fig. 1).

The test shafts were of carburised steel, heat treated to hardnesses ranging from 55 to 61 Rockwell C and ground to a surface roughness ranging from 4 to 5 micro-inches (rms profilometer). The journal diameters were measured at each of the four journals on each shaft The test bearings of solid steel sleeves with copper-lead linings were pressed in the bearing retainers, rough-bored in a lathe, assembled in the housing swivels, and then finished to size with a reamer having a single cutting edge. Bearing diameters were measured at the axial centre and near each end. The nominal dimensions were a shaft diameter of 2 inches and a $1\frac{1}{4}$-inch bearing length. With each oil-feed arrangement two sets of bearings of different clearance were used. These provided D/C ratios of 663 and 403, where D is the journal diameter and C is the diametral clearance. An SAE 20 motor oil was used in all the tests and was maintained at an oil-inlet temperature of 200° F.

In order to obtain characteristic friction data with a minimum of change in bearing surface, tests with each set of bearings were first made in the region of stable lubrication at the higher values of the generalised operating variable, ZN/P, where Z is the absolute viscosity of the lubricant, N is the speed of the shaft, and P is the pressure on the projected area of the bearing. Each test run was made at a constant speed with a number of constant loads which were successively increased at intervals during each run. The apparatus was " warmed up " before the start of each test run and the data were obtained with the bearings in a steady state of temperature distribution.

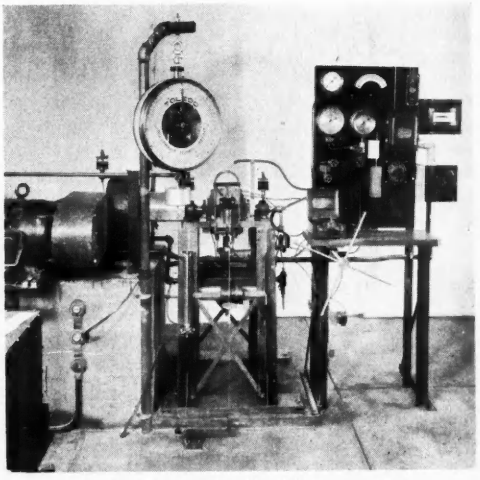


Fig. 1. **The four-bearing friction machine.**

For purposes of comparison, values of the coefficient of friction, f, at $ZN/P = 10$ and $ZN/P = 70$ for each set of bearings tested are given in Table I. The table also lists the average value of f (over the range of ZN/P from 10 to 70) for each set, and the average value for each type of bearing (two D/C ratios). The latter values are used for rating the different types of bearings from the standpoint of friction.

After the tests at high ZN/P, the range of operation with each set of bearings was extended to cover the low values of ZN/P at and below the point of minimum f. In each test the speed and rate of oil flow were held constant and the load was increased until unstable lubrication was reached. Under these operating conditions the bearings tend to change with continued running, hence four consecutive runs under a given set of conditions were made with each set of bearings tested.

Friction data were obtained in the first and fourth test runs with all bearing arrangements operating at 2030 rpm and with 15 cu. in. per min. oil flow. In these tests the bearings were operated at a given load for a period of two minutes and observations of the frictional torque were made at one-minute intervals. When operation was in the region of stable lubrication, the second torque reading was either equal to, or lower than the first. As the loads were increased, however, the bearings eventually reached the unstable operating

*For further technical details of this work, see Oil Holes and Grooves in Plain Journal Bearings, by S. A. McKee and H. S. White, Trans. ASME Paper No. 50-5-9.

TABLE I.—RATINGS OF BEARINGS.

Design of Oil Feed	Bearing set	Friction Ratings: $ZN/P = 10$ Δf	Friction Ratings: $ZN/P = 70$ Δf	Friction Ratings: Average Δf for each set	Friction Ratings: Average Δf for each design	Friction Ratings: Rating*	Load-Carrying Capacity Ratings: First Run: Critical ZN/P for each set	Load-Carrying Capacity Ratings: First Run: Average Critical ZN/P for each design	Load-Carrying Capacity Ratings: Fourth Run: Critical ZN/P for each set	Load-Carrying Capacity Ratings: Fourth Run: Average Critical ZN/P for each design	Load-Carrying Capacity Ratings: Rating†
1 hole in bearing	31	0·00101	0·00149	0·00125	0·00130	A	3·2	3·2	1·7	1·6	A
	51	0·00106	0·00164	0·00135			3·1		1·5		
2 holes in bearing	32	0·00126	0·00187	0·00158	0·00147	B	3·5	3·5	2·6	2·7	B
	52	0·00113	0·00159	0·00136			3·8		2·8		
Axial groove in bearing	33	0·00101	0·00143	0·00122	0·00124	A	3·3	2·9	1·5	1·4	A
	53	0·00101	0·00149	0·00125			2·5		1·2		
4 holes in bearing	34	0·00125	0·00165	0·00145	0·00143	B	5·0	4·4	3·4	3·4	C
	54	0·00115	0·00166	0·00141			3·9		3·3		
Circum. groove in bearing	35	0·00186	0·00340	0·00263	0·00240	C	4·2	4·2	2·4	2·8	B
	55	0·00149	0·00284	0·00217			4·2		3·2		
1 hole in shaft	S31	0·00109	0·00166	0·00138	0·00136	A or B	2·2	2·6	1·8	1·8	A
	S51	0·00107	0·00162	0·00134			3·0		1·8		
2 holes in shaft	S32	0·00112	0·00169	0·00140	0·00143	B	2·7	2·8	2·0	1·9	A
	S52	0·00111	0·00181	0·00146			3·0		1·8		
1 hole with flat in shaft	S33	0·00137	0·00153	0·00145	0·00146	B	7·2	7·4	5·5	5·4	D
	S53	0·00126	0·00166	0·00146			7·7		5·2		

*Based on average Δf for each design. † Based on average critical ZN/P for each design.

condition where the second torque reading was higher than the first—namely, where the friction increased with an increase in temperature.

The critical values of ZN/P at which these transition points occur for the first and fourth runs with each set of bearings are given in Table I. Also listed are the average values obtained with each type. Since the first run with each set of bearings may be affected by the condition of the original surface finish, the values for the fourth run are used as a basis for rating the different types. These ratings provide an indication of the relative load-carrying capacity of the bearings when operating under the given conditions. They are indicated by letters rather than the numerical values.

Data pertaining to the thermal behaviour of these

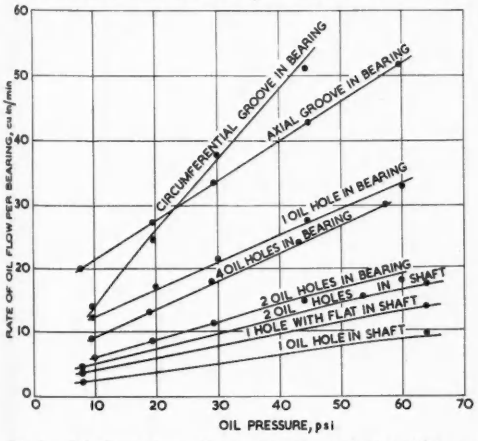


Fig. 2. **Oil-flow versus oil-pressure curves for the different oil feed arrangements when operating at a load of 3008 lb per bearing and a speed of 2030 rpm.**

bearings were obtained in the tests at high ZN/P values under a steady state of temperature distribution. In the analysis of these data consideration is given to the total heat supplied to the bearing. Since the oil-inlet temperature was higher than the ambient temperature, the temperature rise of the bearings was dependent upon both the heat generated by shearing the oil in the bearings and the heat delivered by the oil entering the bearings. The thermal data obtained with all the sets of bearings indicate that, under the conditions covered, the heat-dissipation characteristics of the bearings were dependent chiefly upon the rate of oil flow through the bearings and were practically independent of clearance or the type of hole or groove used.

Measurements of the rate of oil flow at various oil-feed pressures were made also with each set of bearings when operating at a given load and speed, see Fig. 2. Since the rate of heat dissipation of the bearings depended chiefly upon the rate of oil flow through the bearings, data obtained in this phase of the investigation give an indication of the relative heat-dissipation characteristics of the bearings tested under the operating conditions covered. However, these relative values are not necessarily applicable to other conditions.

The influence of the various arrangements of oil holes and grooves upon the behaviour of the bearings is as follows :

One Oil Hole in Bearing. With this arrangement, the absence of holes or grooves on the loaded side of the bearing permits normal development of pressure in the oil film. Consequently, the bearing has relatively low friction and low ZN/P at transition between stable and unstable lubrication. While the single hole does not allow the highest oil flow, it would probably provide adequate heat dissipation for most conditions.

Two Oil Holes in Bearing. The single hole on the loaded side with this arrangement apparently disturbs the normal development of pressure in the oil film, causing a measurable increase in friction and in ZN/P at the transition point. The particular location of the oil hole on the unloaded side is adverse from the standpoint

of oil flow; hence the rate of heat dissipation is somewhat lower than the arrangement with one hole in the bearing.

Axial Groove in Bearing. This arrangement apparently provides a slightly better distribution of oil for the development of the load-carrying film than the arrangement with one hole in the bearing. Consequently, the bearing has low friction and lowest critical ZN/P, and the high oil flow provided is advantageous where forced cooling is necessary.

Four Holes in Bearing. The two holes on the loaded side disturb the development of pressure in the oil film to a greater extent than the arrangement with two holes in the bearing. Critical ZN/P is higher but the friction is comparable. The two holes on the unloaded side are not in advantageous positions, and its oil flow and rate of heat dissipation are comparable to the arrangement with one hole in the bearing.

Circumferential Groove in Bearing. The groove dividing the bearing into two narrower parts increases the friction and causes a relatively high critical ZN/P. The high friction is counteracted by high oil flow and rate of heat dissipation.

One Oil Hole in Shaft. The passage of one oil hole across the loaded portion of the oil film has little effect on both friction and critical ZN/P, which are only slightly higher than for the arrangement with one hole in the bearing. When the hole is exposed to some portions of the loaded area, the oil feed is practically shut off. Consequently, this arrangement results in the lowest oil flow and rate of heat dissipation.

Two Oil Holes in Shaft. With two oil holes for each journal, the disturbance to film-pressure development occurs twice during one revolution, resulting in slightly higher friction and critical ZN/P than with the arrangement of one hole in the shaft. The two holes also provide a greater oil flow and rate of heat dissipation. In this respect it is comparable to the arrangement with two holes in the bearing.

One Oil Hole With Flat in Shaft. The flat at the end of the oil hole causes considerable disturbance to the development of pressure in the oil film, increases the friction, and markedly increases the critical value of ZN/P. The oil flow and rate of heat dissipation are higher than in the arrangement with one hole in the shaft without the flat but not sufficient to counteract the effect of high ZN/P at transition from stable to unstable lubrication.

The results of these tests apply directly to unidirectionally loaded bearings for the particular range of conditions covered. The indicated differences between the various arrangements are not necessarily indicative of more complex conditions where the load varies in both intensity and direction with respect to the bearings. It is believed, however, that the relative values obtained may be useful qualitatively in estimating the over-all effects of various arrangements of holes or grooves under more complex loading conditions, especially if proper consideration is given to conditions present throughout the complete load cycle.

HOLLAND

On the Theory of the Packing Gland for Reciprocating Machines

By D. DRESDEN. (From *De Ingenieur*, Vol. 62, No. 32, August 11, 1950, pp. W69-W71, 3 illustrations.)

A certain amount of practical information regarding packings for glands of reciprocating machines can be obtained from standard handbooks. These, however, do not explain why one type of packing is preferable to another under certain conditions. In this article, an attempt is made to develop a theory of the principles involved.

FIG. 1 indicates schematically the arrangements of the packing gland around the piston rod. The clearance between the rod and the packing material is denoted by z. Although the packing is intended to fit tightly around the shaft, perfect contact over the entire surface of the gland is only obtained at high pressures owing to the irregularity of machined surfaces. At lower working pressures, small irregularly shaped channels remain open and may be regarded as a gap or clearance. These small channels are easily deformable, but the extent of the deformation depends on the nature of the surfaces. In the case of a soft packing, adequate contact over the entire surface may be obtained when surface pressures exceed a certain value, but this value would be too high to allow operation of the piston rod without heating up. Furthermore, if complete contact exists between the rod and the packing, the gap z shown in the figure may be regarded as representing the superficial layer of the packing, with a very small but unknown thickness. This will not basically affect the conditions under consideration.

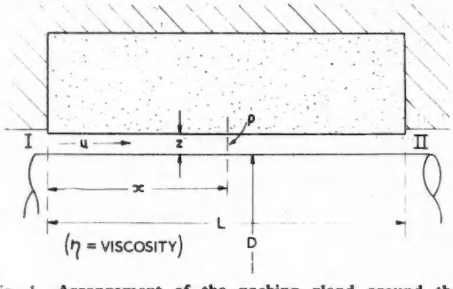


Fig. 1. **Arrangement of the packing gland around the piston rod.**

Under the influence of the variable pressure on the cylinder side I and the assumed constant pressure on the external side II, a fluctuating flow of fluid will occur inside the gap. In these considerations the motion of the piston rod in the packing gland and the mass forces acting on the fluid particles will be disregarded, and it will be assumed that laminar flow conditions exist in the small gap. The validity of these assumptions may subsequently be checked by means of the numerical results obtained. The effect resulting from the ability of the soft packing to take up more fluid at higher pressures will first be investigated. This property of the packing may be attributed either to the elasticity of the walls of the minute channels or to a surface tension existing between the fluid and the medium with which the packing material is impregnated. The latter cause is considered to be the more probable and it should easily explain why a given impregnating substance is more suitable for one type of fluid than for another.

On the basis of these considerations, and using the symbols indicated in Fig. 1, the flow conditions can be expressed by the relation

$$U = -\frac{zD}{4\eta}\frac{\partial p}{\partial x} \quad .. \quad .. \quad (1)$$

If the packing material can take a quantity of M cubic metres of fluid per square metre of its internal surface when the pressure is raised by 1 kg/m², the continuity equation is then given by

$$\frac{\partial u}{\partial x} = -\frac{M}{z}\frac{\partial p}{\partial t} \quad .. \quad .. \quad (2)$$

Eqs. (1) and (2) can be simplified by writing them as

$$u = -\kappa\, \partial p/\partial x \quad .. \quad .. \quad (1a)$$

and

$$\partial u/\partial x = -h\, \partial p/\partial t \quad .. \quad .. \quad (2a)$$

Eliminating u by differentiation then gives

$$\frac{\partial^2 p}{\partial x^2} = \frac{h}{\kappa}\frac{\partial p}{\partial t} \quad .. \quad .. \quad (3)$$

or

$$\frac{\partial^2 p}{\partial x^2} = \alpha \frac{\partial p}{\partial t} \quad .. \quad .. \quad (3a)$$

where $\alpha = h/\kappa$.

Before considering the solution of this equation, it will be useful to examine more carefully the pressure conditions on the cylinder side I, as illustrated in Fig. 2.

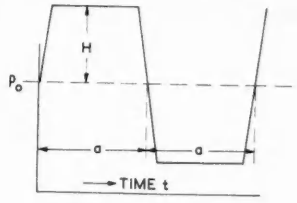


Fig. 2. **Pressure variation at the cylinder end.**

The pressure variation at I can be expressed in the form of a series :

$$p = p_o + \frac{4H}{\pi}\sum_n \frac{1}{(2n-1)} \sin (2n-1)\, \nu t \quad .. \quad (4)$$

where $\nu = \pi/a$.

A solution of eq. (3), using an arbitrary value β_n, is :

$$p = e^{-\gamma x}\,[\cos(\delta t - \gamma x) + i \sin(\delta t - \gamma x)] \quad .. \quad (5)$$

where $\gamma = \sqrt{\beta_n/2}$ and $\delta = \beta_n/\alpha$.

To make this solution agree with eq. (4), use will be made of the fact that the differential equation (3a) is also fulfilled by the sum of an arbitrary number of terms with arbitrary coefficients, of the type given in eq. (5), and is also satisfied by similar sums with either real or imaginary terms only. Therefore, we may write

$$p = A_0 + \sum_{n=1}^{\infty} A_n\, e^{-\gamma x} \sin(\delta t - \gamma x) \quad .. \quad (6)$$

This expression must be identical with eq. (4) when $x = 0$. The coefficients are, therefore,

$$A_0 = p_0$$
$$\beta_n = \pi\alpha(2n-1)/a$$
$$A_n = 4H/[\pi(2n-1)]$$

From this, after a few algebraical transformations, we obtain

$$p = p_o + \frac{4H}{\pi}\sum_{n=1}^{\infty} \frac{e^{-kx}}{(2n-1)} \sin(\omega t - kx) \quad (7)$$

where

$$k = \sqrt{\pi\alpha(2n-1)/(2a)} \quad \text{and} \quad \omega = (2n-1)\pi/a$$

In order to determine u, according to eq. (1a) we differentiate eq. (7) with respect to x. This gives

$$u = \frac{4H\kappa}{\pi}\sum_{n=1}^{\infty} \frac{e^{-kx}}{(2n-1)} \sqrt{2}\, k \cos\left(\omega t - kx - \frac{\pi}{4}\right)$$

Obviously, the expressions for p and u thus determined are only first approximations. As regards p, its value for large values of x (towards the outer end II of the gland) will always be a small-amplitude fluctuation about p_o, since there will always be a constant arbitrary pressure which may be taken as a reference value. As regards u, the total "leakage quantity" for each cross-section x should be equal to zero, when calculated over an integral number of periods of the pressure fluctuation occurring in I. In fact, if the product $u\,dt$ is integrated between limits for t which have a difference equal to $2a$ or an integral multiple thereof, the resultant expression vanishes. This signifies that in each cross-section, and therefore also in the end cross-section, there is as much fluid flowing back in one half-period as there was flowing outwards during the previous half-period. At cross-section II, there is very little fluid in motion, and the capillary flow conditions near this end section are such that it is left dry at periodic intervals.

In view of the above it will be useful to determine how the quantity of fluid leaking through in a half-period is distributed over the various cross-sections. The distribution is determined by calculating the value of $\int u dt$ between time limits which are not integer multiples of a. The integration gives

$$\int u dt = \frac{4H\kappa}{\pi}\sum_{n=1}^{\infty} \frac{e^{-kx}}{(2n-1)} \sqrt{\frac{\alpha}{\omega}} \sin\left(\omega t - kx - \frac{\pi}{4}\right)$$

The calculation of this expression for various cross-sections will now be made, using a numerical example. Referring to eqs. (2) and (2a), let $z = 10^{-4}$ [m], $M = 4 \times 10^8$ [m³/m²], and hence $h = 2 \times 10^{-4}$. Furthermore, in conjunction with eqs. (1) and (1a) let $\kappa = 2{\cdot}5 \times 10^{-7}$, and $D = 0{\cdot}05$, so that $\alpha = 8 \times 10^2$. If H is equivalent to 30 m of water, then in the system of units chosen, $H = 3 \times 10^4$. If we choose $a = 0{\cdot}5$, corresponding to 60 fluctuations per minute, the quantity of fluid considered is the

$$\pi Dz \int u dt, \text{ or in cubic centimetres : } 15{\cdot}7 \int u dt.$$

With these data and using the first three terms only of the series (the contribution of the 3rd term is at most 5 per cent in this case and decreases for larger values of x) we obtain the following numerical values for the various cross-sections :—

x =	0·01	0·03	0·05
cm³ =	3·3	0·9	0·33

Using the same κ, but taking $h = 8 \times 10^{-4}$, which corresponds to a much more porous packing material we have :—

x =	0·01	0·03	0·05
cm³ =	4·0	0·5	0·06

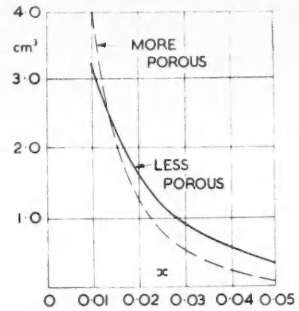


Fig. 3. **Variation of the quantity of fluid leaking through during a half-period.**

From the above rough approximation, it may be concluded that even if a packing with a high fluid-absorbing capacity is employed, a strong pressure may again result in a leakage loss, with pulsating flow conditions on the inner side of the packing gland. It is also apparent from the position of a in the expression for $\int udt$ that a pulsating flow of water will create heavy damping over small distances x when the value of a is reduced, i.e., when the number of pulsations per minute is increased. A more complete picture may be obtained by determining the distribution curves for a number of different values of a regarded as a parameter. Further accuracy would, however, also require taking account of the inertia forces acting on the fluid.

Sweat Cooling

By H. L. WHEELER, JR. and POL DUWEZ. (From *Automotive Industries, U.S.A.*, Vol. 103, No. 2, July 15, 1950, pp. 40, 110-111, 2 illustrations.)

HIGH temperatures encountered in the operation of jet engines have imposed drastic requirements upon materials used in their construction. To meet these requirements, research is directed toward finding materials capable of being efficiently cooled.

Besides the conventional method of cooling by means of a liquid in contact with a material exposed to a high rate of heat transfer, a less orthodox method consists in making the part to be cooled of a porous material and forcing a cooling fluid through the pores. In this scheme, known as sweat cooling, the temperature of the coolant, which moves in a direction opposite to that of the heat flow, increases gradually while passing through the porous material. On emerging from the wall, the coolant forms a protective layer which materially alters the heat transfer from the hot gas stream to the wall. Existence of this protective layer which tends to reduce heat transfer to the wall, and the very efficient exchange of heat between the porous wall and the coolant result in a wall temperature which is much lower than that obtainable by conventional cooling methods.

Tests were performed in a porous cylindrical duct 1 in. dia. and 8 in. long. The temperature of the stream of hot gas passing through the tube could be adjusted between 500 and 2000 F and the maximum velocity was about 2100 fps at a temperature of 1500 F. Gas was produced by burning petrol and air in an especially designed combustion chamber. Cooling gas was injected through a porous cylinder in various quantities with both nitrogen and hydrogen being used as coolants. The porous cylinder was made of copper, stainless steel, or a nickel-molybdenum-iron alloy.

The test section containing the porous cylinder was connected to the burner by a 20-in. straightening tube. Coolant was forced through the specimen from an annular space between the holder and the specimen. Temperature of the hot wall of the porous specimen was measured by thermo-couples.

Accurate determination of the temperature of the gas stream flowing through the test section was extremely difficult. Ultimately, it was found impractical to use anything but a beaded thermocouple supported in two-hole ceramic spaghetti and introduced into the gas stream through a hole in the straightening-tube wall. Weight of the air entering the burner was measured with a conventional rotameter.

Early experimental and analytical work on the subject of sweat cooling showed that a unique relation existed between the characteristic temperature ratio $(T_g-T_w)/(T_w-T_o)$ and the flow ratio Q/W. T_g, T_w, and T_o are respectively, the gas stream, the porous wall, and the coolant inlet temperatures, and Q and W are the weight flow rate of coolant and the weight flow rate of the gas stream per unit area normal to the direction of flow. A theoretical curve demonstrating the relationship of the two ratios is shown in Fig. 1. This curve has been derived assuming that both the coolant and the gas stream have identical properties. Two other curves of Fig. 1 show the results of the experiments using nitrogen sweat-cooled copper and nickel-molybdenum-iron alloy walls. The slight difference in the slope of the curves of the two wall materials is attributed to heat flow along the length of the specimen and the nature of the thermocouple installations.

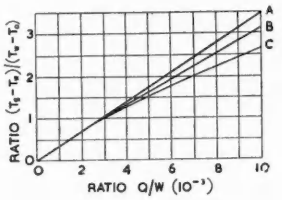


Fig. 1. **Theoretical and experimental curves for different wall materials. The theoretical curve is shown at (A). The other two curves are results of experiments—(B) nickel-molybdenum-iron alloy, and (C) copper.**

It has been found that the nature of the wall material has only a minor influence on the sweat-cooling process, but that hydrogen is a much more efficient coolant than nitrogen from the standpoint of weight required to produce a given cooling effect. This analysis indicates that the parameter which governs the relative cooling efficiencies of various coolant gases is the ratio between the specific heat of the coolant and that of the gas stream.

It has been found that the unit length pressure drop in sweat-cooled tubes is much higher under given conditions than in conventional pipes. Although this high pressure drop per unit length of pipe is due to momentum changes resulting from the injection of coolant, a head loss factor analogous to the conventional friction factor may be derived. This head loss factor has been found to be a function of the flow ratio and the relative densities of the coolant and gas stream. It rises from the value of the conventional friction factor at zero coolant flow to three or more times that value in the range of normal sweat-cooling flows.

In spite of the uncertainties which still exist in the theoretical aspects of sweat cooling, it has proved itself to be a very efficient and an entirely practical method of cooling.

Fuel Injection Pumps with a Wide Delivery Range

By H. RAMBAUSEK. (From *Konstruktion*, Vol. 2, No. 6, 1950, pp. 180-183, 6 illustrations.)

The fuel pump design described in this article has a delivery adjustable over a wide range of values and is also characterised by other features, for instance, increased torque at lower speeds. This design makes it possible to reduce the number of pump types required and thus simplifies manufacture. Details of tests carried out so far are also given.

THE object of this work was to develop a pump which could be used for widely different sizes of internal combustion engines. Normally, an engine with a fuel consumption of about 90 mm³ (0·0055 cu in.) per injection is provided with a fuel pump with plungers of 6-8 mm (15/64-5/16 in.) diameter, and an engine with a consumption of about 400 mm³ (0·0244 cu in.) per injection requires plungers of 12 mm (31/64 in.) diameter. It is, however, possible to design a single type of fuel pump which gives favourable results for both classes of engine.

DESIGN DETAILS AND OPERATION

The new pump is provided with a plunger having a diameter large enough to supply the maximum quantity of fuel required in the range considered. With a conventional design, the stroke would then have to be reduced to such an extent at low outputs that accurate adjustment of the delivery would be impossible in view of the compressibility of the fuel. The new pump is, therefore, designed so that the fuel delivered by the plunger is divided into two streams, one of which goes to the injection nozzle while the other passes through a return valve into the suction chamber of the pump.

The relative adjustment of the two streams is obtained by means of a relief valve which is initially set according to the amount of fuel required by the engine. The delivery then remains constant as long as the engine speed is not varied. Part-load regulation is as usual by rotation of the plunger. Thus, if an engine only requires one quarter of the fuel delivered by the plunger (with a plunger diameter twice the required size), then three quarters of the fuel (at full load or part load) will go back through the return valve, this being achieved without altering the effective stroke controlled by the regulator. The system is applicable to pumps with a number of elements for multi-cylinder engines and enables individual adjustment of the pump elements. The elements are then controlled as a combined unit, either manually or by means of the regulator. As the full effective stroke is utilised under all conditions, fine adjustment is possible irrespective of the maximum delivery value.

Fig. 1 shows details of the new pump. An orifice plate *a*, situated between the pump elements *b*—*c* and the pressure valve *d*—*e*, prevents excessive delivery of fuel to the engine. This causes an increase in pressure over the plunger, sufficient to open a relief valve *f*—*g* in order that the excess fuel may return into the suction space *h*. Although the orifice plate is the same for engines of a given class, the adjustable relief valve *f* makes it possible to adapt the delivery to the fuel requirements of engines of different horsepower ratings included in this class of engine.

The proportions of the quantities of fuel are affected by the following variables :—(1) the orifice *i*, (2) the stiffness of the spring *k* of the pressure valve *d*—*e*, (3) the time-area characteristic of the relief valve *f*—*g*, (4) the stiffness and preload of the relief valve spring *l*, and (5) the injection pressure to which the closing spring of the injection nozzle is set.

By choosing suitable values for these quantities, it is possible to vary the delivery characteristic of the fuel pump and to adapt it to the fuel requirements of the engine.

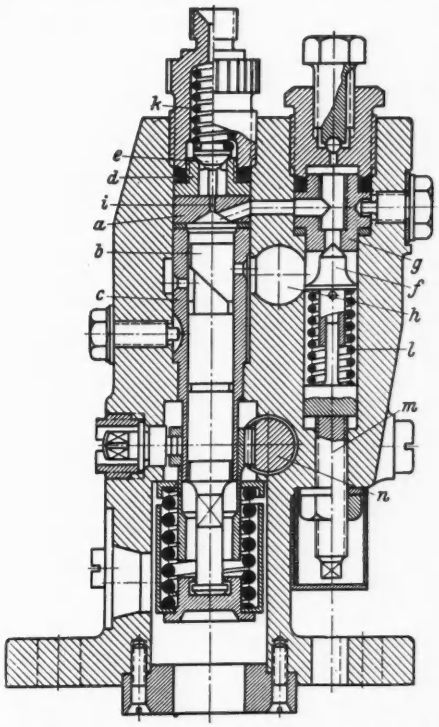


Fig. 1. **Section through a two-cylinder fuel pump with increased delivery range.**

(*a*) Orifice plate ; (*b*) plunger ; (*c*) pump cylinder ; (*d*) pressure valve seat ; (*e*) pressure valve head ; (*f*) relief valve head ; (*g*) relief valve seat ; (*h*) suction space ; (*i*) orifice ; (*k*) pressure valve spring; (*l*) relief valve spring ; (*m*) set screw ; (*n*) rack.

At lower running speeds, the plunger speed is correspondingly reduced. The increase in pressure ahead of the orifice plate is then also less pronounced and this has the effect of allowing less fuel to pass back through the relief valve into the suction space and, consequently, more fuel is delivered to the injection nozzle. Thus, at lower engine speeds, the quantity of fuel injected per stroke is increased. It is, therefore, possible to obtain a required torque characteristic over a limited horsepower range by using appropriate values for the cross-sections of the orifice *i*, the valve seat *g* and the stiffness of the relief valve spring *l*.

The reason for making the quantity of fuel delivered per stroke dependent on the engine speed is that, since at lower running speeds the air delivery ratio is higher, a greater quantity of fuel can be burnt with a smoke-free exhaust, and this corresponds to an increase in the engine torque. With an appropriately determined pump characteristic, the engine can be run just below the smoke limit over the entire speed range, in order to obtain an efficient utilisation of the air available to the engine even at lower speeds.

With the conventional pump types, the pump delivery increases at higher speeds owing to the corresponding reduction of the leakage losses ; the result is a tendency of the engine to overspeeding, which is entirely eliminated with the new pump. In fact, the pump characteristic can be developed in such a way that at very high speeds the fuel quantity injected per stroke is limited, and this helps considerably to relieve the governor action.

If a given pump is to be used on a different type of engine, sufficient adjustment will generally be obtained by turning the set screw *m* on the relief valve to vary the delivery. After the initial adjustment, the pump is operated in the same way as the conventional pump types, regulation being obtained by means of the rack *n*. The set screw *m* of the relief valve is adjusted and locked in position. For mass production of a given type of engine, the screw *m* may be omitted and replaced by shims under the valve spring *l*.

If the adjustment obtained by means of spring *l* is insufficient, for instance, in a case where a much smaller engine than normally corresponds to the plunger diameter is to be considered, then the orifice plate *a* may be replaced by another plate with a different hole diameter, chosen so that, in conjunction with the relief valve, the most favourable torque curve will be obtained.

TEST RESULTS

Tests on a pump with a plunger of 12 mm diameter showed that, after initial adjustment, the ratio of the two fuel streams going to the nozzle and the relief valve remains constant at a given speed when the effective pump stroke is varied. The delivery curve plotted against the regulating range is a straight line, as shown in Fig. 2. Using a rack with a stroke of 10 mm, the pump delivery was 375 mm³ per stroke at a pump speed of 750 rpm, when operating as a conventional pump. It was, therefore, too large for the engine which required 90 mm³ per stroke over the same regulating range at the same speed. The relief valve was, therefore, so adjusted that the ratio of the two branch streams was 1/3.

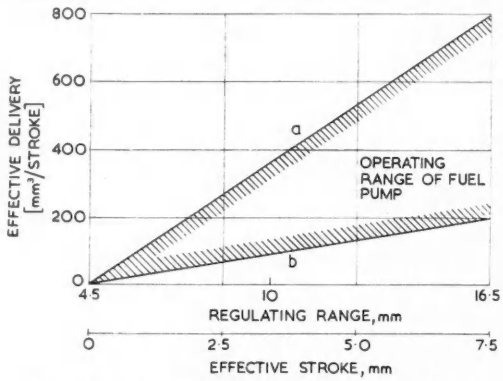


Fig. 2. **Regulation of fuel pump delivery characteristic in the operating range.**
a = normal characteristic ; *b* = reduced characteristic.

Tests showed that this ratio varied at the lower end of the speed range (200 rpm), so that instead of 90 mm³, approximately 160 mm³ of fuel was injected per stroke (see Fig. 3). Further tests confirmed the possibility of varying this characteristic by changing the spring stiffness of the relief valve spring and the orifice of the throttling plate, so as to obtain any required pump characteristic over a wide range, with the pump delivery maintained at the required values. Engine tests indicated an increase of more than 25 per cent in torque in the lower speed range. The fuel consumption under full- and part-load conditions at maximum speed was approximately the same as with a conventional pump. At reduced speeds there was a decrease in the fuel consumption, amounting to approximately 10 per cent at 1/2 to 1/3 load.

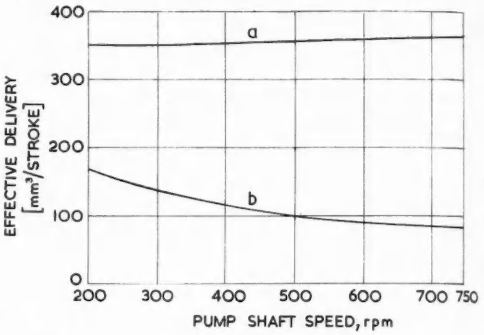


Fig. 3. **Fuel delivery plotted against pump speed for 10 mm regulating range.**
a = normal characteristic ; *b* = reduced characteristic. Fuel flow ratio 1/3.

The variation of the pump characteristic need only be determined once for each type of engine, using various spring stiffnesses for the relief valve spring and various orifices. If extremely accurate adjustment is not required, it is sufficient to determine the ratio of the two branch streams going to the nozzle and the relief valve, which is readily achieved. The relative adjustment of the individual pump cylinders to each other is extremely simple and the measured differences in the delivery at full load or part load are extremely small (less than 1 per cent at full load, and from zero to 5 per cent at part load).

Delivery failures at low speeds do not occur with the new pump design, since at low pumping speeds the ratio of the two stream branches is varied in such a way that more fuel reaches the injection nozzle and the effect of the orifice plate is practically eliminated. This has the advantage that, if necessary, the engine may be started in a part-load position, so that a special starting position for the rack will be unnecessary.

CONCLUSIONS

The new pump can be used for a wide range of engine sizes and, thus, a reduction in the number of pump types can be achieved, so that the additional use of a relief valve and orifice plate is amply justified, besides offering the advantages already mentioned. For small-size engines, the use of a pump of the design under consideration, with a plunger diameter much greater than in conventional designs, offers particularly appreciable advantages. If the pump elements and nozzles are situated so close together that the fuel lines are practically eliminated, then even the smallest quantities of fuel can be accurately metered and supplied to the engine.

The pump used for the tests had an unusually large plunger diameter of 12 mm. With the relief valve inoperative, the pump delivered 375 mm³ of fuel per stroke, the effective stroke of the plunger being 3·3 mm. This determined the upper limit (line *a*) of the delivery range in Fig. 2. The maximum effective pump stroke was approximately 8 mm corresponding to a maximum delivery of about 900 mm³ per stroke. With the relief valve operating, and an effective stroke of 3·3 mm, the fuel streams were adjusted to give a delivery of 90 mm³, represented by line *b* in Fig. 2. This corresponds to a plunger diameter of 6 mm, but is not the lowest limit of

the adjustment range. The engine ran smoothly on the lower line *b*, and this shows that the entire delivery range between the lines *a* and *b* is reliably controlled. Thus, using even a single plunger diameter of 12 mm, it appears possible to cover almost the entire delivery range of the pump types most commonly used.

The pump characteristic is, therefore, represented no longer by a single line, but by an area within which the operating line is drawn (Fig. 2). To avoid excessive throttling effects, it is proposed to divide the entire delivery range into smaller intervals, and to use either two pump types of 7·5 and 12 mm or three types of 6, 9 and 12 mm plunger diameter. The external dimensions of the two-cylinder fuel pump conform to the rules for standard pump sizes. The pump can be used with an external drive or can be driven by the engine, and multiple-element versions can, of course, be built as a single unit.

CZECHOSLOVAKIA

New Direct-Acting Directional Relay for Ring-Type Networks

By Š. Matěna. (From *Elektrotechnický Obzor*, Vol. 38, No. 23-24, December, 1949, pp. 607-613, 8 illustrations.)

A new direct-acting relay is described which protects transformers of ring-type networks in the case of reverse short-circuit currents. It is claimed that this relay is much simpler and cheaper than those in general use.

European low-voltage ring-type networks use high-capacity fuses for protection at the intersections of feeders. Fig. 1 shows the usual arrangement of such a network. The network is fed by four high-voltage transformers, V_1—V_4, across the low-voltage transformers T_1—T_4. To prevent the blowing of the fuses at the intersections when a fault occurs in the transformers or the lines connecting them, directional relays *ZR* are connected on the secondary sides of the low-voltage transformers. These relays act on the breakers *SV* when fault current flows from the network in the reverse direction.

Directional relays of present-day practice are mainly of the secondary type, working on the wattmeter principle. They are fed by current and voltage transformers and use accessories. These relays were originally very complicated; they had to serve, e.g., also for the automatic distant re-connection of the transformers following switching operations in the high-voltage transformer station. This task of automatic re-switching has been abandoned with the advent of the newer types of directional relays and the complete protecting device consists nowadays of three secondary relays of three voltage and current transformers, inductances and resistances, auxiliary contacts, and the disconnecting coil.

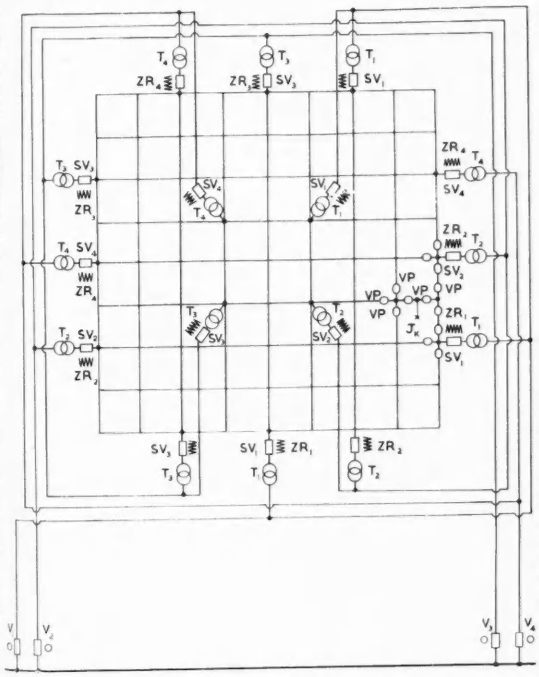


Fig. 1

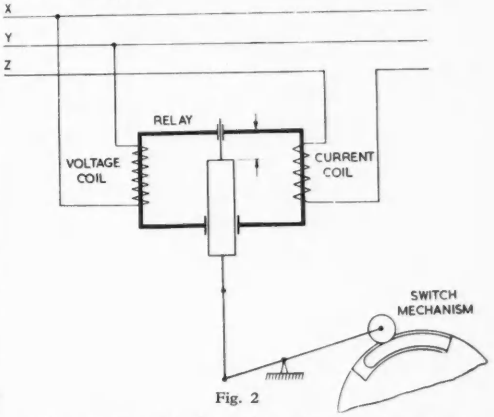


Fig. 2

The relay described here is a primary relay and acts directly on the switch mechanism of a circuit breaker. It develops the necessary force to disconnect in the case of a reverse short-circuit current. This relay means a considerable simplification of the protective system for networks. The principle of the relay can be followed from Fig. 2. It has a voltage and a current coil in each phase. All the coils are separately arranged on the outer columns of a laminated iron core. The centre column is movable and, when drawn in, acts with sufficient strength on the disconnecting mechanism of the circuit breaker. The current coil is in series with one phase, while the voltage coil is connected across the other two phases.

The action of the relay is explained by Fig. 3 for the case of a three-phase short circuit. One current coil of the relay is in the *Z*-phase and the corresponding voltage coil across the phases *XY*. If the short-circuit is

symmetrical in the three phases, the vector diagram does not alter in shape and direction, but becomes smaller, corresponding to the voltage drop from the fault to the relay. The current in the voltage coil I_{nxy}, during the fault, also remains nearly perpendicular to the voltage vector XY. The current vector of the current coil, I_{3kz}, is inclined at a small angle to the voltage vector Z, as the resistance of a cable, mainly for small cables, is much larger than the inductance. Correspondingly, the angles between the voltage and current coils of the relay are of the order of 30 degrees, i.e., they have large parallel components. If the short-circuit occurs in the network, the currents as shown in the diagram magnetise the relay core in the same sense. The stray field in the central column of the core is small and the column does not move up. If, however, the short-circuit is on the side of the feeding transformers, the current in the current coil flows in the opposite direction. The voltage and current coils in this case magnetise the core in opposite senses and produce a large stray field in the movable centre column, which is drawn in, thus acting on and disconnecting the breaker.

The relationship between voltage and current has been determined for the new relay and plotted in Fig. 4 for the cases of different angles between the current vectors of the current and voltage coils. The abscissae show scales for two different current coils, one used on 315-kVA transformers and the other on 150-kVA transformers. The curves show that the relay does not act with currents smaller than 200 per cent of the normal.

Calculations were carried out to determine the range of action of the relay. The calculations show that in the case of a short-circuit in the network, the angle of the currents in the voltage and current coils is smaller than 30 degrees for cable cross-sections of less than 0·15 sq. in. Comparing the position of the short-circuit curves of the network with the characteristics of the relay, it can be seen that the dud section for the relay action is not more than 7 ft of cable length for a network of 5 MVA power, or 13 ft for a network of 2·5 MVA power. If the short-circuit is at a larger distance from the relay, the latter acts correctly, i.e., it does not disconnect if the fault is in the network, but does so if it is on the high voltage side.

In the case of a short-circuit on the high-voltage side, the breaker of the H.V. transformer acts first. The fault then becomes supplied from the network and the action of the directional relays follows. It can be seen from the short-circuit curves of the network in Fig. 4 that the relay voltage is still larger than 50 per cent and the relay therefore acts reliably even when the phase angle is larger than 60 degrees.

The directional relays were tested in the direct circuit of a 150-kVA transformer, the reactance of which was 1·85 per cent, permitting a maximum short-circuit current of 5800 A. An 84-ft long, 0·15 sq. in. 3-core cable was used to simulate the network, and varying types of short-circuits were produced, i.e., one, two and three-phase short-circuits. Each type of test was carried out twice, with current flowing in opposite directions. The voltage drop across two phases of the cable was applied to the voltage coil. The relays acted on a breaker of 600 A nominal current.

The tests with the new type of relay were satisfactory and proved that it acts according to the characteristics in Fig. 4. The relay is sufficiently sensitive for use in low-voltage networks, and functions correctly, except where the fault is less than 7 to 13 ft distant from the relay. It is, however, not as sensitive as the customary secondary type relay, which works with small forces and moments. However, such a sensitivity is not necessary in low-voltage networks. On the other hand, the new type of relay has definite technical and economic advantages, and a patent application was recently filed with the Czechoslovak Patent Office.

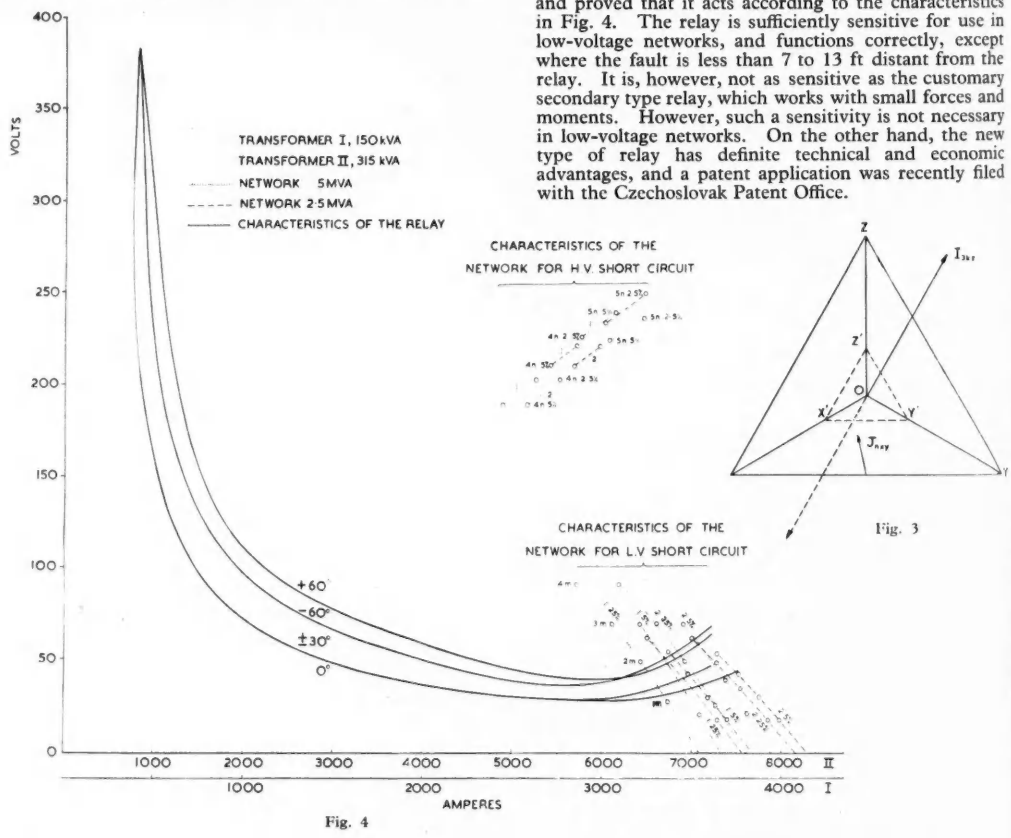


Fig. 4

Fig. 3

A Systematic Investigation into the Band-Saw Cutting of Aluminium and its Alloys

By E. Von Burg. (From *Schweizer Archiv*, Vol. 16, No. 2, February 1950, pp. 33-43, 18 illustrations.)

The clamped light-alloy bar is drawn into the saw by weights so that the feed pressure is constant. The amount of material removed per kWh and the saw-tooth pressure are then functions of the feed pressure and height of cut. The surface qualities and chip formation are observed. The advantages of a constant feed pressure and a small height of cut are stressed.

Band-saw work needs as much care and attention as work with any other machine tool. Correct choice of the saw blade, cutting speed, and feed pressure (automatic if possible) results in optimum conditions and in reduced wear. The present paper shows the influence of cutting height and feed pressure on cutting efficiency, i.e., the amount of material removed per kWh, and on the cutting pressure per saw tooth. The chip formation is observed and the effect of the mechanical properties of the material on the required feed pressure is traced. The rectangular bars to be saw-cut were fastened to the sliding machine table, which was loaded by weights so that the bars were fed into the saw with a given constant feeding force. The saw speed was 110 fps when running light. The cutting time was measured with a stop watch and the power consumption with a watt-meter. The rate of feed of the bar, the cutting efficiency (amount removed per kWh) and the tooth pressure were calculated. Motor efficiency and consumption under no-load conditions were included in the calculations.

Fig. 1 shows the blade profile used, but an undercut profile would have been more advantageous as shown by the known curves of Fig. 1a. The tooth pitch is important, 3 to 4 teeth should be cutting simultaneously, yet there should be sufficient space between teeth for the chips. The teeth must be carefully set and the blade well guided. Freshly ground teeth usually cut deeper, and therefore consume more power, than teeth that are well run-in. The time of cutting a given bar correspondingly increases as the fresh blade starts cutting. Before tests were started, the blades thus had to be run in until power consumption and cutting time remained approximately constant. Chemical compositions and mechanical properties of the test materials are shown in the following tables :

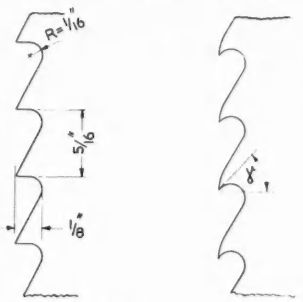


Fig. 1. **Saw profile as used for tests.**

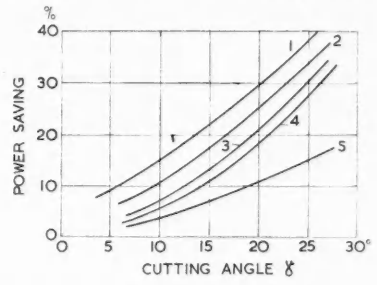


Fig. 1a. **Advantages of cutting angle** γ.
1 — 32-tsi steel
2 — cast steel
3 — cast iron
4 — 55-tsi steel
5 — pearlitic cast iron

	Cu	Si	Mn	Mg	Fe
Aluminium	—	0·1	—	—	0·3
Al-Si-Mg Alloy, wrt.	—	1·1	0·3	0·8	0·4
" " cast	—	5·2	0·7	0·7	0·3
Al-Cu-Mg Alloy	4·5	0·3	1·2	1·4	0·4

	0·2 proof stress	Ultimate tensile strength	Elongation 10 × dia	Ultimate shear strength	Brinell Hardness
	psi	psi	%	psi	—
Aluminium	5500	11650	23·0	9380	21
	3560	10100	23·0	9100	22
Al-Si-Mg Alloy, cast not hardened	11400	23850	4·2	18600	53
fully hardened	42700	47800	1·0	33200	116
Al-Si-Mg Alloy, wrt. soft	10650	20450	25·3	12800	39
fully hardened	55200	61000	9·5	32400	110
Al-Cu-Mg Alloy, cast not hardened	23450	32100	2·9	25750	78
fully hardened	33500	46800	2·2	35100	114
Al-Cu-Mg Alloy, wrt. soft	16750	33800	16·3	21450	64
fully hardened	43600	66700	15·3	36700	112

The correct feed pressure is of great importance. Too great a pressure leads to badly scored cutting faces and too small a pressure to powdery chips, which are rubbed off the material rather than cut. Lubrication greatly improves the surface qualities. The correct pressure depends on the strength of the material and the height of cut. A small height requires less feed pressure and results in more material being removed per kWh. If the correct feed pressure is obtained automatically, for instance by suitably chosen weights attached to the feed table, uniform clean machining and reduced wear of the saw blade can be guaranteed even if the operator is unskilled. The blade must always be lubricated, e.g., by tallow.

The amount of material removed per kWh (cutting efficiency) can be calculated as

$$V = K \frac{bhv}{W},$$

where b is the length of cut, h the height of cut, v the rate of feed, W the required effective cutting power (Watt), and K a dimensional factor depending on the units chosen. The three graphs of Fig. 2 show V as a function of height of cut as well as feed pressure. The relation between feed pressure and rate of feed is indicated in Fig. 5 for wrought materials. It is significant for the curves of Fig. 2 that the cutting efficiency falls rapidly with increasing height of cut. For a constant height, V obviously increases with increasing feed pressure. Whilst tests on a lathe* have shown that the cutting efficiency is lower for cast alloys than for wrought alloys, no such indication is given by these tests with the band-saw, allowance being made for the fact that the cast Al-Si-Mg alloy,

*Schweizer Archiv, 161, 1944, No. 10, and Schweiz. Techn. Rundschau, 1945, No. 48/49.

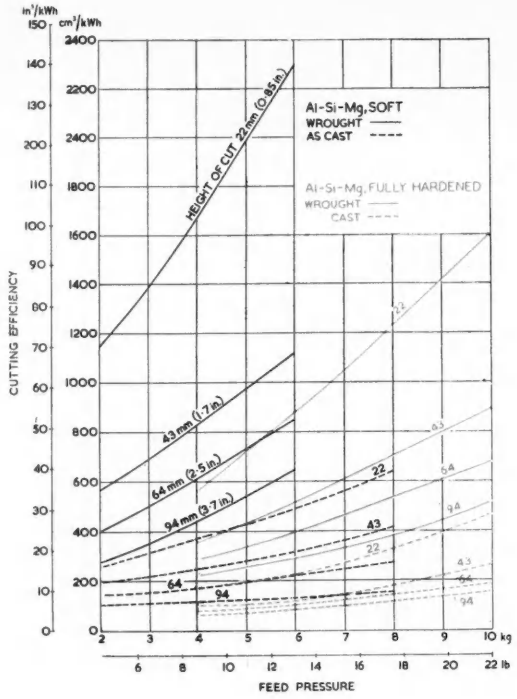


Fig. 2a

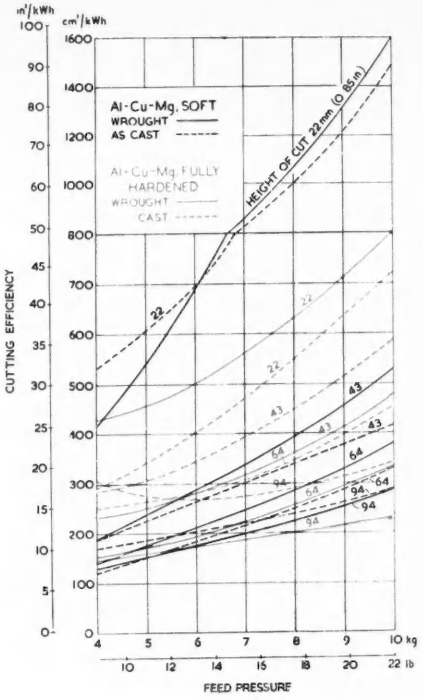
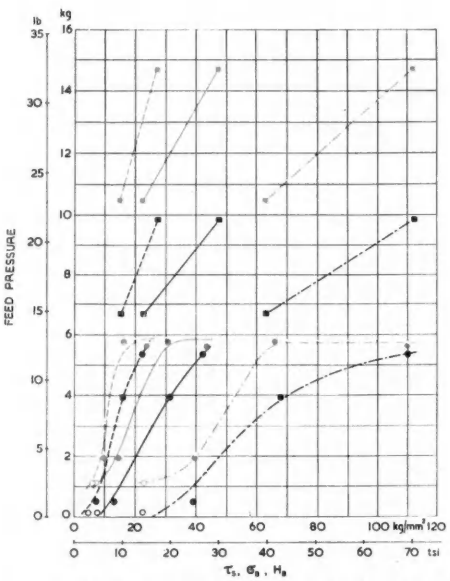


Fig. 2b



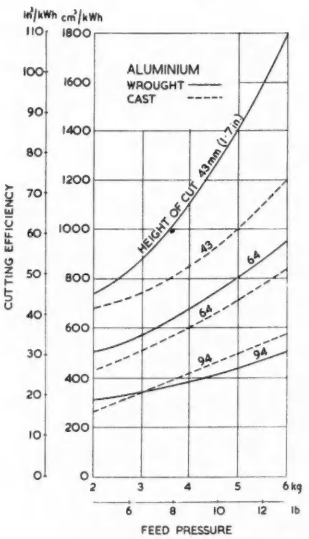


Fig. 2c

Figs. 2a–2c. **Cutting efficiency, cubic inches of metal removed per kWh, as a function of height of cut and feed pressure.**

Fig. 3 (left). **Feed pressure for a given cutting efficiency as a function of shear strength τ_S, tensile strength σ_B, and Brinell hardness H_B of wrought light alloys.**

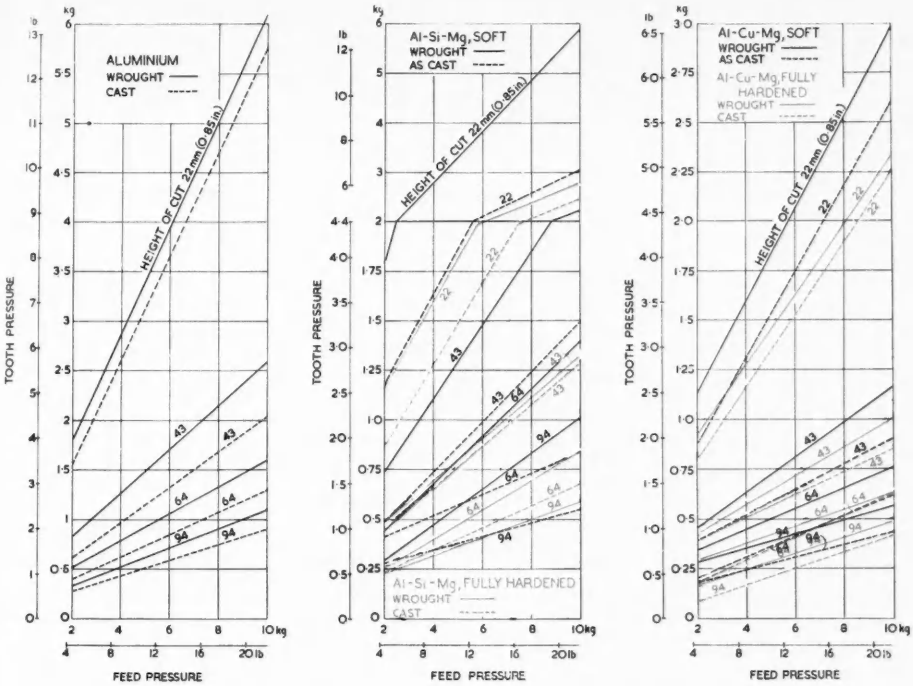


Fig. 4. **Tooth pressure as a function of height of cut and feed pressure.**

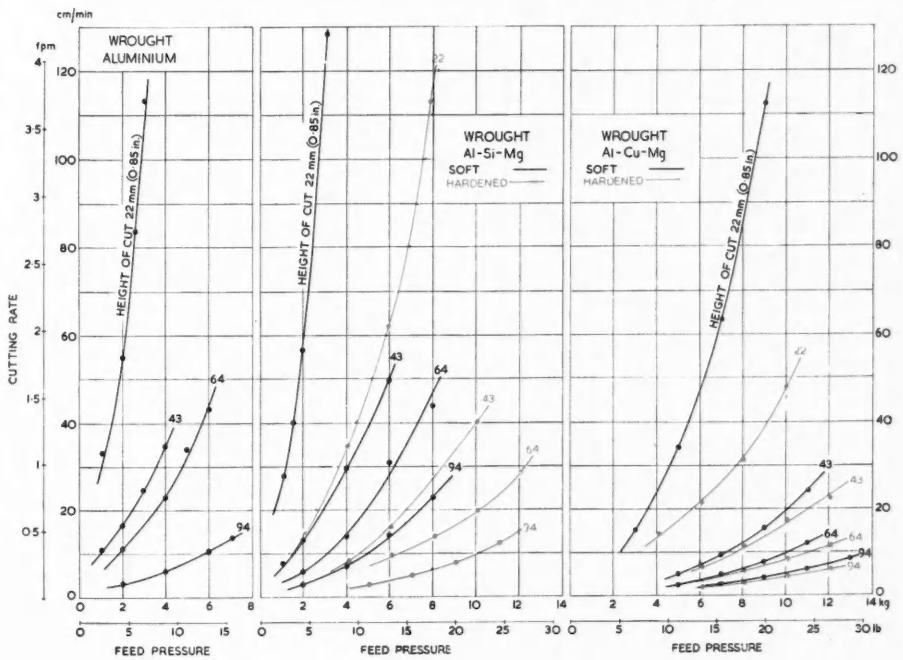


Fig. 5. **Rate of feed as a function of feed pressure for wrought light alloys.**

because of its greatly increased Si-content (5 per cent against 1 per cent of the wrought alloy), has a greatly reduced cutting efficiency. Fig. 3 finally shows the feed pressure required for a given cutting efficiency as a function of the various mechanical properties of the wrought alloys. As is already known, the Al-Cu-Mg alloy is more difficult to cut than the Al-Si-Mg alloy, since it requires a higher feed pressure for the same cutting efficiency and height of cut. Similarly, the fully hardened materials require a higher feed pressure than the softer materials of the same composition.

The tooth pressure is $P = K' \frac{W}{vz}$,

where W is again the power required, v again the rate of feed, z the number of active saw teeth, and K' another dimensional factor depending on the units chosen. The tooth pressures decrease with increasing height of cut, but increase linearly with increasing feed pressure, see Fig. 4. The soft material shows a higher tooth pressure than the hardened material because, under otherwise equal conditions, the saw cuts thicker chips off the soft material than the hardened material. This effect is more pronounced than the influence of the higher strength of the hardened material. For equal cutting speeds as in these tests, the thickness of chips must increase almost linearly with the rate of feed. On the other hand, for equal feed pressures, the rate of feed of aluminium and soft Al-Si-Mg alloy are about the same (Fig. 5), hence the tooth pressures must be about the same for the two materials. Similarly, since for a given tooth pressure the differences in rate of feed between the soft and the hard Al-Cu-Mg alloy are small, but are large as between the soft and the hard Al-Si-Mg alloy, the differences between the respective tooth pressures must follow the same rule.

GERMANY

Progress in Ultrasonic Methods of Materials Testing

By O. RÜDIGER. (From *Stahl und Eisen*, Vol. 70, No. 13, June, 1950, pp. 561-565, 10 illustrations.)

In contrast to X-ray and electromagnetic methods, ultrasonic methods have only entered the practical field in the last ten years. They may conveniently be divided into four main groups: intensity, image-formation, echo and resonance methods. Principles, development and applications of these methods are reviewed in this article.

INTENSITY METHODS

THESE are historically the oldest; a schematic representation is given in Fig. 1. They are based on the fact that faults in the material reflect the sound waves, and hence the sound intensity behind such points is practically zero. The reflection is due to a (usually gas-filled) cavity having a " sound resistance " which is very different from that of the metal (by "sound resistance " is meant the product of density × sound velocity). Due to great differences in density and sound velocity between gases and metals, their sound resistance differs by a factor of 10^5, so that at a gas-metal boundary, reflection is almost complete. This reflection will take place at even the finest hairline cracks, using frequencies of several million cps. However, this very fact also increases the difficulty of conducting the ultra-sound into the test piece. The coupling between generator and test piece is effected by means of liquids (water, oil or mercury), and quartz oscillators are used almost exclusively both as generators and detectors of ultrasound.

One of the principal difficulties associated with the method is the formation of standing waves in the metal, whenever the thickness is an integral number of half-wavelengths. They can, however, be eliminated by a periodic change of frequency (" wobbling "). Another difficulty is presented by the need for reproducible couplings between source and test object.

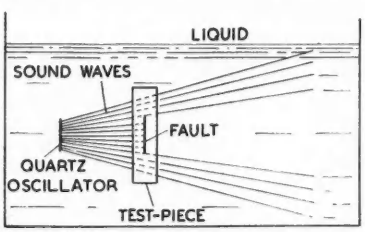


Fig. 1. **Schematic representation of the intensity method of testing.**

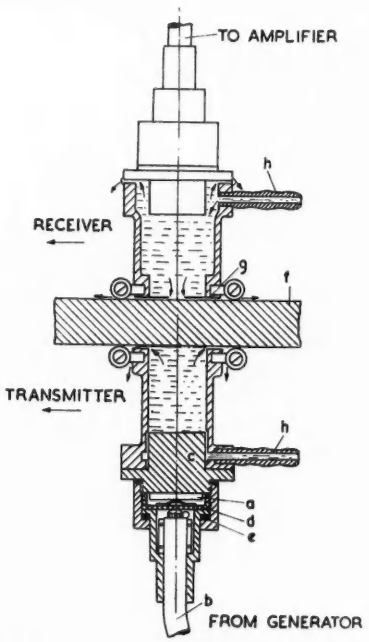


Fig. 2. **Ultrasonic tester (according to A. Trost).**
(a) Quartz oscillator; (b) high-frequency cable; (c) metal block; (d) insulator; (e) packing; (f) test-piece; (g) diaphragm; (h) water inlet.

Fig. 2 illustrates an apparatus due to A. Trost[1] for testing boiler plates. Running water is used as coupling medium between the plate and the quartzes. Standing waves are eliminated by frequency-wobbling. A telephone or glow-lamp serves as fault indicator. Frequencies of 1 Mcs are used.

Another method, due to J. Götz[2], is illustrated by Fig. 3. Oblique incidence of the waves eliminates troublesome reflections between the surface and quartzes. Flexural vibrations are induced in the plate, and Fig. 4 shows that the transparency to sound goes through a maximum value with varying angle of incidence. If the plate is passed between the quartzes at the angle of maximum transparency, the intensity drop due to faulty spots will be specially marked. An amplifier working through a relay can give acoustic or other signals when a fault is found. A frequency of 475 kcs is used, and with a 15 mm dia. detector quartz, relatively small cracks can be found. The procedure is restricted to plates of uniform thickness.

O. Rüdiger and others[3] developed a test instrument for small metal objects, employing an ultrasonic scanning beam of 1·5 mm dia. and 10 Mcs frequency. Standing waves are eliminated by means of random frequency modulations within a 1 Mcs band. This enables non-parallel plates to be tested. Fault registration is photographic ; a small electric bulb is rigidly linked with the specimen, and is controlled through a wide-band amplifier so that it is extinguished when a fault is reached in scanning. Moving with the specimen, it thus yields a complete " sound photograph " of the faults. The limit of resolution is 0·5 mm. Similar instruments are described in English[4] and Russian[5] literature.

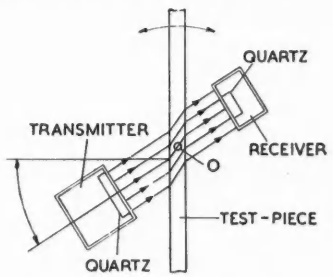


Fig. 3. **Ultrasonic tester (according to J. Götz).**

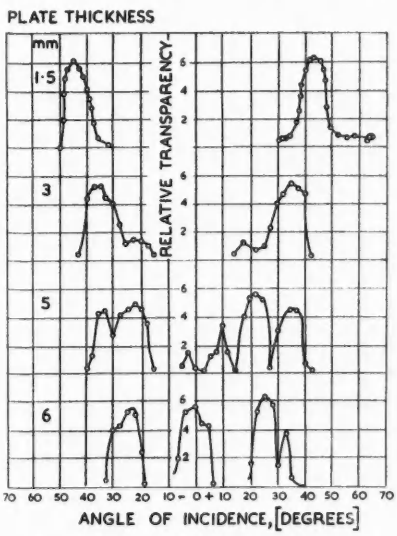


Fig. 4. **Transparency to sound as a function of the angle of incidence.**

IMAGE-FORMATION METHODS

An ultrasound lens has been developed by R. Pohlmann[6], consisting of a lens-shaped vessel of thin sheet copper and filled with xylol or carbon tetrachloride. The receiver is a flat trough, containing a suspension of fine aluminium tinsel. On the passage of a sound wave, the disc-shaped aluminium particles will be lined up parallel to the wave-front and will thus become good reflectors of light. The apparatus itself is rather bulky (about the size of an electron microscope). Mercury is used as a coupling medium. The highly automatic apparatus is compressed-air driven. Frequencies of 3 and 7 Mcs are used. As the sound lens has a very shallow focus, the location in depth of any fault can also be determined by a calibrated focussing arrangement. The sensitivity is indicated by the following figures : metal bars 1 mm wide and spaced at 1 mm distance can be resolved with a wavelength of 0·85 mm ; also drill-holes in aluminium of 0·5 mm dia. are detectable.

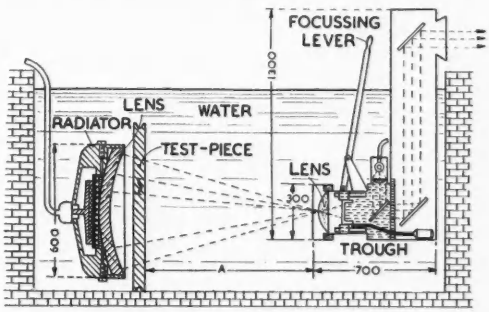


Fig. 5. **Ultrasonic image formation for large test-pieces.**

For large objects, Pohlmann uses a water tank (Fig. 5), and a quartz mosaic as source[7]. A collimator lens produces a convergent beam. The source has a radiating area of 500 mm and works at 560 kcs. Faults of 10 mm extension can still be located. Though clean surfaces are not essential, it is advisable to remove forge scale.

Instruments for serial tests have also been built by Pohlmann[7], incorporating suitable arrangements for quick processing. Cracks 0·4 mm long and 10 ⁻⁴ mm wide can be detected.

ECHO METHODS

In this method, sound pulses are sent through the material, and reflections from any boundary are received by a separate receiver, or by the generator itself during intervals between the pulses. In the latter case, a switch-circuit, which alternately connects the quartz with sender and receiver, is required. For a uniform test object and identical coupling, the reflected pulse will always appear the same on an oscillograph screen. It is suggested that the echo might be used for triggering off the next pulse, and the resultant pulse repeat frequency used for testing.

F. A. Firestone[8] and R. B. De Lano[9] describe an instrument called a " Reflectoscope " which employs pulses of 1 microsecond duration. Using a frequency of 5 Mcs gives 5 complete waves in each pulse. The pulse repeat frequency is 60 cps. A diagram of the generator is shown in Fig. 6. Oscillations are generated

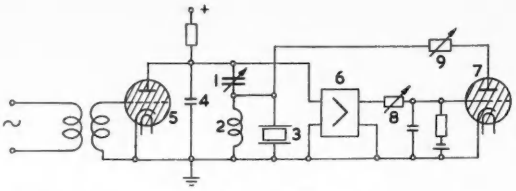


Fig. 6. **Pulse generator for echo-sounding method (according to F. A. Firestone).**

in the circuit (1, 2), with the controlling quartz (3) in parallel with the inductance. The oscillations are triggered off by a mains-controlled thyratron (5) discharging through the condenser (4). The voltage pulse is applied through an amplifier (6) to a second thyratron (7), the anode circuit of which is in parallel with the quartz. When the second thyratron is conducting, the quartz is shorted, thus terminating the ultrasonic pulse. The delay element (8) determines the time of striking of (7), and the resistance (9) controls the shunt circuit. Between the pulses the quartz is switched into the receiving circuit (not shown). The echoes appear as " blips " on an oscillograph, the timebase of which is synchronised with the mains frequency. The distance between two blips on the screen gives the transit time of the pulse directly. In a fault-free material, reflections will only be produced at the outer boundaries. Any faults will show up as intermediate echoes, and from their position on the screen the fault can be located in depth.

A similar instrument has been developed in England by C. H. Desch and others[10], employing frequencies of 2·5, 2·25, 1·25 and 5·8 Mcs, a separate receiving quartz and a pulse repeat frequency of 50 cycles.

Echo instruments are specially suited for detecting cracks, blowholes, etc., in large forgings or castings[11]. Tool steels can also be tested, it having been found possible to distinguish liquations from mechanical discontinuities[12]. H. R. Clauser[13] describes an instrument capable of locating faults 6·5 mm below the surface. Faults of 0·5 mm dia. in turbine blades could also be detected.

A limitation of the usefulness of the method lies in the finite relaxation time of the pulse generator, setting a lower limit to registrable transit times corresponding to a wall-thickness of about 1·5 cm. This difficulty can be overcome by interposing a metal cylinder between generator and object, thus increasing all transit times by a fixed amount[14]. Oil or mercury films are used for coupling purposes, and the compressibility of the coupling layers is compensated by means of thin metal foils. Oblique sound incidence is sometimes used with advantage, e.g., in testing for welding faults in plates. For plates of a thickness comparable with the wavelength employed, Firestone[12] uses shear-oscillations of the quartz, inducing waves in the dispersive region of the plate.

Another application is described by P. Bastien and others[15]. If 2·5 Mcs pulses are sent into large chromium-molybdenum steel forgings normalised at 850°C, echoes of the type shown in Fig. 8a are obtained for a plate thickness of 240 mm. If the plate is now heated at 950°C, only the normal echoes are observed (Fig. 8b). The anomaly is attributed to a resonance effect. Figs. 7 and 8 show that with a frequency of 2·5 Mcs (2·1 mm wavelength) only a grain size of 1 mm will cause anomalous echoes, while after refining to 0·2 mm grain size, the anomaly disappears. For a frequency of 1·25 Mcs (4·2 mm wavelength) the parasitic echoes are absent in both cases. Corresponding observations have been made with copper, armco-iron and stainless steel. It was found that 0·8 mm grains no longer give rise to the effect, and thus it cannot be due to scattering. It may be assumed that crystalline grains with a diameter of exactly one half-wavelength are brought into resonance and act as secondary emitters. Recrystallisation and other similar phenomena could possibly be investigated by such methods. Echo instruments could also be used for wall-thickness measurements. Instruments based on the same principle have also been developed for the measurement of elastic constants[16].

RESONANCE METHODS

These are chiefly employed for wall-thickness measurements[17]. A valve-maintained quartz oscillator is used, with a motor-driven rotary condenser in the oscillatory circuit giving a periodic frequency modulation within a certain band. If the sound is applied to the test object, it will resonate with the natural frequency of the object. This raises the power consumption of the oscillator and thus the anode current of the output valve. By differentiation of this current, a sharp pulse is obtained and applied to the Y-plates of an oscillograph, while the X-plates are given a voltage proportional to the frequency. The sweep is synchronised with the frequency change. The position of the " blip " gives the wall-thickness with an accuracy of 1·2 per cent.

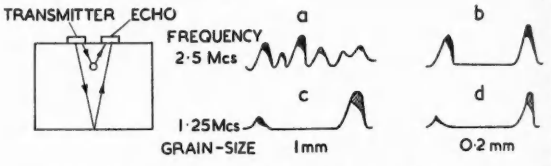


Fig. 7. Test arrangement.

Fig. 8. Echo signals obtained.

Figs. 7 and 8. **Echo tests in steel plates.**

W. C. Hitt[18] describes such an instrument for thicknesses between 0·4 and 12 mm. For thicker walls, the harmonic frequencies are used. The audio-frequency modulation of the ultra-sound may be used in place of an oscillograph. On traversing the frequency band, the modulation tone will rise to a maximum corresponding to the resonance. Using suitable frequencies, thicknesses from 0·5 to 300 mm can be measured, provided the surface is large enough for the quartz to be coupled to it. An application to the testing of concrete beams is described by E. Meyer[19].

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On the Principles of Electrodeposition of Metal Powders

By G. WRANGLÉN. (From *Transactions of the Royal Institute of Technology, Stockholm*, No. 37, 1950, 30 pp., 21 illustrations.)

The formation of powdery and spongy deposits on the cathode and the factors controlling it are treated in some detail. The effects of concentration, current density, temperature, convection and the presence of neutral salts are considered. The influence of hydrogen and metal overvoltages on the pH value of the cathode film is discussed. Powder formation on the cathode in the cases of fused-salt electrolysis and copper, iron, nickel, zinc and cadmium electrolysis is described and analysed. Other theories of powder formation are criticised.

A. DIFFERENT METHODS OF ELECTROLYTIC PREPARATION OF METAL POWDERS.

ELECTROLYTIC preparation of metal powders is based on two substantially different principles. The metal may be deposited in a powdery or spongy form, or it may form a coherent brittle deposit, which may be ground to powder. The method to be used depends chiefly on the shape of the polarisation curve of the metal (cathode potential-current density relation), Fig. 1.

Metals with a steep polarisation curve (1) tend to form excrescences when deposited from their simple salts, and are thus easy to obtain as powdery deposits. Moreover, such metals are usually soft even in their deposited condition and, therefore, are difficult to grind. Thus, direct deposition is the natural method of production of powders of metals with low overvoltage (e.g. Ag, Pb, Cu, Zn, Cd). On the other hand, the transition elements (high overvoltage, sloping curve (2)), tend to give coherent deposits. Under conditions favouring high polarisation, they become brittle due to inclusion of finely divided hydroxide, and are therefore easily ground. This method is thus suitable for the iron group (Fe, Ni, Co).

The deposition of brittle deposits is not considered further here. The formation of powdery and spongy deposits is treated on the basis of the author's experiments and the available literature.

B. FACTORS CAUSING THE FORMATION OF POWDERY OR SPONGY DEPOSITS ON THE CATHODE.

The following two main factors should be distinguished :

1. Depletion of the cathode film. Under conditions of high depletion, the metal grows out into the bulk solution—where the metal ion concentration and conductivity are higher—in order to maintain the current.

2. Hydroxide in the cathode film. Precipitated hydroxide may settle on the cathode surface, insulate the metal beneath and stop its growth at such points. Thus, again, an incoherent deposit is formed.

Hydrogen evolution at the cathode is sometimes a contributory factor in the loosening of the deposit.

C. DEPLETION AND SHAPE OF THE POLARISATION CURVE.

The extent to which a powdery deposit is caused by a depletion of the cathode film depends on the shape of the polarisation curve (Fig. 1).

With a steep polarisation curve (1), a local increase of current density may easily occur, as this corresponds to only a small change of the deposition potential. This will be the case where the deposit forms needles, at the point of formation of which the current density is high. With a sloping curve (2), the tendency towards needle-formation is counteracted by the much larger change of potential required ; consequently, coherent deposits are obtained. Addition of alkali salts tends to flatten the curve even more (3). The mechanism of deposition

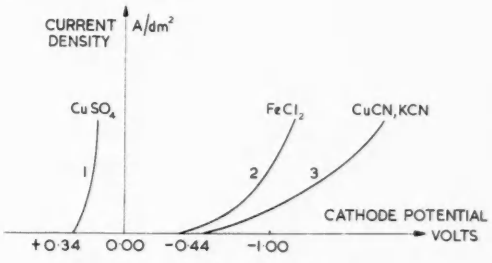


Fig. 1. Polarisation curves.

in this case is probably a cathodic reduction of anions of the type $Cu(CN)_2^-$ or $Cu(CN)_3^{--}$, etc. Metals deposited from the complex state also give smooth deposits as a rule. For the deposition of metal powders, simple salts are therefore used, without the addition of complex-forming substances. Neutral salts may be added to increase conductivity ; they also tend to make the deposit more uniform.

Conditions favouring depletion of the cathode film are : low ion concentration of the deposited metal, low temperature, high current density, slight stirring, and the presence of neutral salts in high concentration. Under these conditions, loosely coherent deposits are easily obtained. Although addition of a neutral salt counteracts the formation of needles, at the same time it favours the deposition of a spongy deposit and thus yields a finer powder. Addition of an acid may have the same effect, but the result is complicated by an increase in hydrogen evolution.

An extreme case of the depletion effect may be observed in the formation of metal blacks, e.g., platinum black, at very high current densities. Evolution of hydrogen may sometimes assist in loosening the deposit, but it may also make it coarser due to the convection caused, which counteracts depletion.

D. DEPLETION AND TIME OF ELECTROLYSIS.

The deposition of powder does not begin immediately after the current has begun to flow, owing to the time required before the cathode film becomes depleted. The following relation was obtained from experiments on copper sulphate : $\frac{i\sqrt{t}}{c} = \text{const.}$, where i = current density, c = molarity, t = depletion time. Assuming that no convection occurs, that the salt obeys Fick's law, and that the transport numbers are constant, theory gives the diffusion coefficient as

$$D = \frac{(1 - n_c)^2}{\pi F^2} \frac{i^2 t}{c^2},$$

where n_c = transport number of cation ; F = the Faraday constant ; i, c, t as above, t being the time when there is a sudden drop in current. The concentration at

the cathode is then negligible compared with that in the bulk of the solution, c. Since the diffusion coefficient depends upon temperature, the change in the effect with temperature follows from the equation.

Since, at high current densities, the time t is very short, the effect is not of practical importance. However, as the deposition proceeds in time, the cathode surface will increase ; thus, the current density decreases and tends to make the deposit more coherent. In practice, therefore, the deposit must be removed frequently from the cathode or otherwise the resultant powder will be too coarse.

E. FORMATION OF HYDROXIDE IN THE CATHODE FILM.

Precipitation of the hydroxide in the cathode film is promoted by conditions which foster hydrogen evolution, as this causes depletion of hydrogen ions near the cathode. Only precipitated hydroxide (gel-form) will cause the formation of a powdery deposit, while in a colloidal solution (sol-form) it will have the opposite effect of causing a fine-grained, hard deposit, especially of nickel. Precipitated hydroxide is adsorbed locally, causing an incoherent deposit, and will also provide a support for hydrogen bubbles. The inclusion of hydrogen bubbles in the deposit (known as "pitting" in electro-plating) will not occur until hydroxide flocks are precipitated at the cathode. The hydroxide may be that of some baser metal present in the electrolyte.

The depleting conditions mentioned above also tend to deplete the cathode film of hydrogen ions, i.e., increase the pH difference between the cathode film and the bulk solution. Hydrogen ions may be transferred to the cathode in 4 different ways :

1. Diffusion of hydrogen ions.
2. Electric migration of hydrogen ions.
3. Convection of electrolyte.
4. Dissociation of buffering substances in the immediate vicinity of the cathode.

The quantity of hydrogen ions, A_h+, transferred to the cathode per unit time and area may thus be written as

$$A_h + = D\frac{c_b - c_e}{\delta} + \frac{i\,n_h}{F} + f_{\text{conv}}(A_h+, \text{pH}) + f_{\text{diss}}.$$

Here D = diffusion coefficient ; c_b = concentration in the bulk ; c_e = concentration at the electrode surface ; δ = thickness of the diffusion layer within which the concentration gradient is assumed to be linear ; i = current density ; n_h = transport number of the hydrogen ions ; F = Faraday constant. The convection term is dependent on the amount of hydrogen bubbles evolved, owing to their stirring action, and also on the amount of hydroxide present ; hence it is dependent on the pH in the cathode film. The difference in pH between cathode film and the bulk solution is large if the diffusion term is large.

The second term is small if the current is mainly conducted by ions other than hydrogen. A lowering of temperature decreases the third and fourth terms and the diffusion coefficient.

Conditions of overvoltage, in their control over the amount of hydrogen evolved and, thus, over the pH, exert a stronger influence than the above factors. This may preponderate over the depletion effect and, thus, in some cases, powder formation may be favoured by a *high* temperature and a *low* current density.

F. EXAMPLES OF FORMATION OF POWDERY OR SPONGY DEPOSITS ON THE CATHODE.

1. Fused-salt Electrolysis.

A powdery deposit is almost always formed if the electrolysis is carried out below the melting point of the metal deposited.[1] This is connected with the fact that at the high temperature of the fused salt, all metals are deposited with virtually no polarisation and, consequently, the tendency towards lowering the cell voltage can easily assert itself. A soft, powdery deposit is formed even at low current densities.[2] It seems particularly difficult to obtain a coherent deposit by fused salt electrolysis, as there are no means at hand for flattening the polarisation curve.

2. Copper.

In the case of deposition of copper powder, depletion alone is usually the cause of formation. The deposition in practice is carried out in strongly acid solutions[3], and is then accompanied by hydrogen evolution. In weakly acid solutions at intermediate current densities, a fine, dark red powder may be deposited, without the co-deposition of hydrogen.

Investigations were carried out to determine the influence of acidity and neutral salts. Arranged in order of particle size of powder as estimated by microscopic observations (50×), the conditions of electrolysis gave the following table :

Relative particle size of copper powder deposited at 12 grams/litre Cu, 50° C, 4 A/dm².

	Solution	Nature of deposit
1.	Neutral solution	Coherent deposit and large dendrites.
2.	+ 100g/l H_2SO_4	Fine dendrites.
3.	+ 10g/l H_2SO_4	Red sponge and fine dendrites.
4.	+ 50g/l Na_2SO_4	Uniform red sponge.
5.	+ 200g/l Na_2SO_4	Brown sponge.
6.	+ 10g/l H_2SO_4, 50g/l Na_2SO_4	Dark red, dense sponge. Finely divided.
7.	+ 10g/l H_2SO_4, 200g/l Na_2SO_4	Voluminous red sponge. Finely divided.
8.	+ 10g/l H_2SO_4, 400g/l Na_2SO_4	Voluminous red sponge. Finely divided.
9.	+ 400g/l Na_2SO_4	Brownish black, dense sponge. Finely divided.

There was no substantial difference in particle size between 6, 7 and 8.

From these experiments the conclusion may be drawn that a finely divided copper powder may be produced at a lower current density and a higher temperature than is used commercially, if stirring of any kind, including that caused by hydrogen evolution, is avoided. The acidity should be kept low ; about 10g/l H_2SO_4 is sufficient to prevent contamination by oxides. The conductivity is increased by the addition of neutral salts, which also tend to make the powder more uniform. The commercial requirement of a powder of high weight per unit volume may also be attained by suitably adjusting the acidity and the concentrations of added salts.

3. Iron.

Although iron powder is produced commercially by grinding, there are many patents dealing with the direct deposition of iron powder[4]. A method proposed by Friederich[5] was investigated because it seemed the most promising both from theoretical and practical points of view. His solution contained 15g/l Fe as $FeCl_2$, 100g/l NH_4Cl and was neutral. A low temperature and a current density of 10 A/dm² was recommended.

Preliminary experiments showed that the pH value of the solution was of great importance to the form of the deposit, and therefore care was taken to keep it constant during the experiment. An antimony electrode and calomel electrode were placed close together and at a remote distance from the iron electrodes. Hydrochloric acid was added continuously from a burette at such a rate that a zero current instrument in the compensating circuit showed no deflection. As the antimony electrode was not quite stable in the concentrated chloride solution, periodic checks were made with a glass electrode

and a valve potentiometer on samples of the electrolyte; the compensating circuit was adjusted accordingly. In this way the pH value was kept constant within 0·2 unit.

The amount of ferric iron and iron hydroxides in the solution was determined by titration. Before every experiment, ferric iron was removed by filtration at pH 5-6. Air oxidation, however, produces traces of ferric iron; oxidation becomes more severe when ferrous hydroxide begins to appear. With the addition of ammonia, this takes place at pH 6·5; at this value, therefore, considerable buffering sets in. The amount of hydroxide present could be kept within close limits by the addition of acid.

The cathode surface and various cross-sections of the deposits in each experiment were studied microscopically. In order to investigate the influence of pH, experiments were made with pH values 3, 4, 5, 6, 6·5 at 20° C and at 50° C. At the higher temperature, a coherent deposit was obtained in all cases until ferrous hydroxide was precipitated at pH 6·5, when the deposit immediately changed to a powdery structure. At 20° C, on the other hand, there was a gradual change in structure as the pH was raised. This is explained by the greater difference in pH between the cathode film and the bulk of the solution at a lower temperature. In a neutral solution, powder is deposited as easily at 50° C as at 20° C. At 90° C, however, a coherent deposit is again formed, even without stirring. At higher current densities, a finer powder is formed. This is also the case if the electrolyte contains nitrates or other oxidizing agents[6].

Most specifications on direct deposition of iron powder refer to neutral or alkaline solutions with higher concentrations of conducting salts and containing precipitated hydroxides. However, even in the case of iron, a powdery deposit may be formed due to the depletion effect alone. Thus, with the above solution, a powdery deposit was obtained at 25° C, pH 2·5, 20 A/dm², and without stirring. As the pH was increased to 3·5, no appreciable change in the deposit was observed. However, a much finer and looser deposit may be obtained from a neutral solution containing ferrous hydroxide than from an acid solution with depletion alone as the powder-forming factor.

Increased convection tends to give a coarser powder, and may also bring about increased hydrogen evolution, which means that the current efficiency with respect to the metal is lowered. More important, the precipitated hydroxide and hydrogen bubbles are removed from the cathode before they have a chance of loosening the deposit. In practice, therefore, it is essential to avoid stirring, if a fine powder is to be obtained.

4. Nickel.

Electrolytic preparation of nickel powder is alo usually done by grinding down a coherent deposit. It is found that it is more difficult to obtain a powdery deposit of nickel from its simple salts than in the case of iron, especially at low temperatures and low concentrations. However, if ammonium salts are added, pure nickel can be obtained in powder form if very high current densities are used[7]. The formation of a loose deposit is facilitated by small additions of metals such as Ag, Cu, Sn and Cd[8]. A purely powdery deposit is most easily obtained in ammoniacal solutions[9]. Thus, under the conditions 10g/l Ni as $NiCl_2$, 250ml/l conc. NH_4OH (giving a pH of about 11), 15 A/dm², 50° C, stationary electrolyte, a powdery deposit was obtained with a current efficiency of 90 per cent. It could be removed from the cathode by washing with water.

5. Zinc.

The formation of so-called "zinc sponges" has been thoroughly studied since the end of the nineteenth century, mainly with the purpose of avoiding such formations. It was established that low current density, high temperature, and the presence of nobler metals and certain oxidising agents were favourable conditions. Sponges are never formed in sufficiently acid solutions, but are conspicuous in alkaline zincate solutions. It was considered that sponge formation is due to the precipitation of hydroxide in the cathode film, and this theory received further support from investigations into the overvoltage of hydrogen on zinc.

At low temperatures, the hydrogen overvoltage is so high that virtually only zinc is deposited. At higher temperatures, the depletion of hydrogen ions in the cathode film causes the precipitation of the hydroxide, which is included, resulting in a spongy deposit. An increase of current density favours an incoherent deposit; however, at high current densities, the hydrogen overvoltage becomes so high that zinc alone is deposited again, forming a coherent film, as there are no longer any disturbances at the cathode. In a neutral solution, depletion and hydroxide formation thus counteract each other, with the latter factor preponderating as a rule. Nobler metals present are deposited before the zinc. As a rule, they have a lower overvoltage for hydrogen and, thus, provoke sponge formation.

In zincate solutions, powder formation is favoured by *low* temperature and *high* current density, contrary to the case of neutral solutions[10]. This suggests that in alkaline solutions the governing factor is the depletion effect. The ease with which sponge formation takes place may be connected with the high concentration of sodium hydroxide.

In neutral solutions, if very high current densities are used, sponge formation is again observed, due this time to the excessive depletion of zinc ions and the subsequent evolution of hydrogen at the cathode. Thus, spongy zinc deposits of virtually the same appearance may be formed under three substantially different conditions, viz.:

1. In acid zinc salt solutions at *high* current density and *low* temperature.
2. In neutral zinc salt solutions at *low* current density and *high* temperature.
3. In alkaline zincate solutions at *high* current density and *low* temperature.

At present, strongly alkaline zincate solutions seem to be used mostly for the production of zinc dust, as they are easier to control[11, 12, 13].

6. Cadmium.

Cadmium has polarisation properties similar to zinc; hence, similar conditions of sponge formation may be expected. The main difference is that cadmium is not amphoteric and is a nobler metal than zinc. A loose, crystalline powder is almost invariably deposited from cadmium solutions without addition agents. An acid cadmium salt solution, electrolysed at high current density, is used for the preparation of cadmium powder for analytical purposes[14]. A cadmium sponge used in alkaline storage batteries of the Swedish type is produced under similar conditions.

Investigations were made into a solution containing 50g/l Cd as chloride and varying amounts of NaCl. The influence of the latter was very marked. Under the different experimental conditions listed below, the addition of 100g/l NaCl was found to give the greatest variation, and such a solution was studied in greater detail. The conditions were as follows:

pH 6				pH 1			
(1)	20° C	0·5	A/dm²	(5)	20° C	0·5	A/dm²
(2)	20° C	5	,,	(6)	20° C	5	,,
(3)	80° C	0·5	,,	(7)	80° C	0·5	,,
(4)	80° C	5	,,	(8)	80° C	5	,,

In the case of pH 1, the solution was made 0·1 N with respect to hydrochloric acid ; in the case of pH 6, it was neutralised with NaOH until the precipitate of $Cd(OH)_2$ became permanent. No stirring was provided.

Conditions most favourable to sponge formation were those of No. 3 above. From microscopic observations it was concluded that current density and temperature influence the sponge formation of cadmium in the same manner as in the case of zinc, and the explanation in terms of hydrogen and metal overvoltage is the same.

If the deposits from the solution containing 50g/l Cd and 100g/l NaCl are arranged in increasing particle size of powder, the following table is obtained (the numbers referring to the conditions above) :

3. Grey sponge.
1. Partly dense sponge, partly larger crystals.
4. Aggregations of well-developed crystals.
8. Aggregations of well-developed crystals.
2. Thin scaly flakes.
6. Dense aggregations of well-developed crystals.
7. Well-developed crystal plates.
5. Large aggregations of well-developed crystals.

Conditions 6 or 8 may be recommended for the practical preparation of cadmium powder. Sulphate solutions were found unsuitable for the purpose, as reduction to sulphide may take place at the cathode.

Without added NaCl, a coherent deposit was obtained in all cases. With 300g/l NaCl, a rather coarse grey sponge was formed even under the least favourable condition 5. At higher current densities, a very fine black sponge was deposited. Addition of alkali salts here also favours sponge formation.

Experiments at high current densities showed that at first the co-deposition of hydrogen decreases, especially at low temperatures. Above a limiting current density, however, hydrogen is again evolved due to excessive depletion of metal ions in the cathode film. A black spongy deposit is then formed due to the depletion effect supplemented by hydrogen evolution. A solution containing $CdCl_2$ only (50g/l Cd) was electrolysed at

(*Concluded on page* 372)

CZECHOSLOVAKIA

The Breaking of Valve Springs

By P. KOHN. (From *Strojnický Obzor*, Vol. 30, No. 5, May, 1950, pp. 65-70, 6 illustrations.)

This article surveys the causes and measures for the prevention of valve spring breakages. It further deals with a fact which has hitherto been neglected i.e., the influence of fluctuations in the rotation of the cam shaft on the oscillation of valve springs, which in many cases is likely to be the cause of apparently inexplicable spring breakages.

THE breaking of valve springs is one of the most frequent causes of failure of internal combustion engines. Although breakdowns of this kind are not very serious in most cases, the loss of time and money involved in repairing makes an investigation into this problem necessary.

The causes of breakage of valve springs may be either faults in material or in manufacture, that is, faults in chemical composition or in heat treatment, the presence of slag, and scratches or other damage to the surface. Breakage may also be due to overstressing, either by the basic load or by superimposed oscillations. The location and appearance of the fracture in many cases point to its cause.

A fracture due to faults in material or in manufacture starts at the faulty spot, and proceeds in steps ; careful examination during manufacture and long tests under working conditions should prevent failures of this description.

A fracture due to overstressing starts at the point of maximum stress (in the case of a helical spring, on the inside), and the plane of the fracture includes an angle of 45 degrees with the axis of the wire. In the case of slight oscillations, all coils are approximately equally stressed, and all share the risk of breaking. In the case of resonance oscillations, the first effective coils at both ends of the spring are stressed most. A fracture at a point between 1 and $1\frac{1}{2}$ turns from either end thus points to resonance, and fractures of the central coils may be caused by excessive stresses due to the basic load.

Spring design is usually based on the simplified assumption that the spring is without mass, and that the motion of the valve is absolutely positive. The dimensions of a spring are calculated to obtain forces which guarantee, on the one hand, that contact in the valve mechanism is maintained even during the period of maximum retardation (having due regard to friction) and, on the other, that the outlet valve does not open during the suction stroke. The number of coils should be an integer plus $\frac{1}{2}$, i.e., the ends of the spring should be diametrically opposite. At least $\frac{3}{4}$ of a coil on either end should be ineffective so that there is a whole number of effective coils.

In the following equations, D [cm] is the pitch diameter of the spring, d [cm] is the wire diameter, i is the number of effective coils, f_0 [cm] is the compression of the spring when the valve is closed, f_1 [cm] is the lift of the valve. The forces, in kg, which the spring exerts are then :—

for the closed valve,

$$P_0 = 103750 \frac{d^4}{i D^3} f_0 \quad .. \quad .. \quad (1)$$

for the open valve,

$$P_1 = 103750 \frac{d^4}{i D^3} (f_0 + f_1). \quad .. \quad (2)$$

The average torsional stress on the inside of the spring, in kg/cm², due to the basic load, i.e., the stress when the valve is half open, is

$$\tau = 264000 \frac{d}{i D^2} \left(f_0 + \frac{f_1}{2} \right) y \quad .. \quad (3$$

The alternating stress, i.e., the difference between the stresses in the central and end positions, is

$$\tau_a = 264000 \frac{d}{i D^2} \frac{f_1}{2} y. \quad .. \quad .. \quad (4$$

The coefficient y has regard to the curvature of the wire, and it is plotted in Fig. 1 as a function of D/d. The Smith diagram (Fig. 2) for carbon spring steel shows permissible values of the torsional stress. The

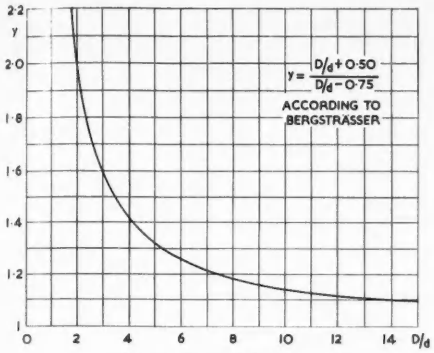


Fig. 1. **The coefficient** y.

thinner wires endure higher stresses than the thicker ones because they are strengthened to a higher degree during the cold-drawing process. When using this diagram, it should be borne in mind that the choice of a smaller stress than is permissible does not necessarily increase the safety ; it will be shown rather that the safety may even decrease, and that a slightly excessive stress may be advantageous in some cases.

It should also be considered that, according to J. A. Haringx,

$$\frac{f_0 + f_1}{L} < 0{\cdot}8125 \left[1 - \sqrt{1 - 27{\cdot}4 \left(\frac{D}{L}\right)^2}\right], \quad ..(5)$$

to avoid buckling of the spring, where L is the free length of the spring, expressed in the same unit as the diameter D. This risk disappears for $L/D < 5{\cdot}24$.

As an actual spring is not without mass and is oscillating, the alternating component of the spring is increased to

$$\tau_{ac} \mathrel{\hat{=}} \tau_s \left[1 + \frac{1}{15} \frac{C_\mu \, n_e}{f_1 \, b}\right] \quad .. \quad (6)$$

n_e is the natural frequency of the first mode of vibration of the spring, in min^{-1}, and is

$$n_e = 2180000 \frac{d}{i D^2} = 16{\cdot}5 \frac{\tau_s}{f_1 \, y}. \quad (7a, b)$$

b is the coefficient of damping, and, according to Hussmann, is 2 to 3 sec^{-1}.

C_μ is the amplitude in cm of the μ-th harmonic of the valve lift curve, wherein

$$\mu = \frac{n_e}{n} \quad .. \quad .. \quad .. \quad (8)$$

is the order of the harmonic which causes resonance oscillations at a speed of the cam shaft of n revolutions per minute ; resonance arises only if n_e/n is an integer.

Because of the uncertainty of the value b, equation (6) has merely a qualitative significance, and it may be assumed that $\tau_{ac} = 1{\cdot}5 \, \tau_s$. The amplitude C_μ can be found by the harmonic analysis of the valve lift curve. Fig. 3 shows, as an example, the analysis of a harmonic cam. The amplitudes of the harmonics appear in the form of a wave, and decrease rapidly with increasing μ, on the average proportionally to $(1/\mu)^3$. If it is assumed that $C_\mu = K(1/\mu)^3$, we obtain, by using equation (8),

$$C_\mu = K \left(\frac{n}{n_e}\right)^3. \quad .. \quad .. \quad (9)$$

By combining eqs. (9), (7b), and (6), we obtain

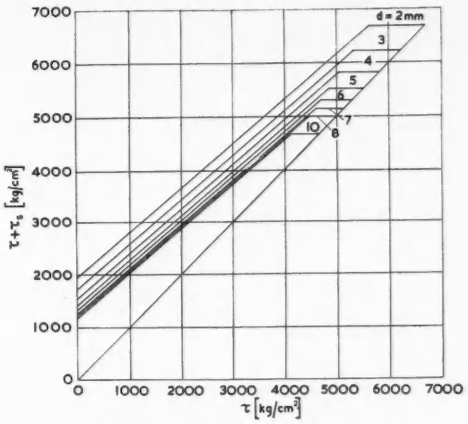


Fig. 2. **Smith diagram for carbon spring steel.**

$$\tau_{ac} = \frac{f_1 \, y}{16{\cdot}5} \left[n_e + \frac{K n^3}{15 f_1 \, b \, n_e}\right]$$

$$= \tau_s + \left(\frac{f_1 \, y}{16{\cdot}5}\right)^2 \frac{K n^3}{15 f_1 \, b \, \tau_s} \quad .. \quad (10a, b)$$

This relation shows that the actual alternating component of the torsional stress is large for small values of n_e and τ_s, particularly if there is a high speed n of the cam shaft, and a small coefficient of damping b. On the other hand, the actual stress does not differ greatly from the stress due to the basic load for large values of n_e and τ_s, so that the actual stress is large also for large values of n_e and τ_s. Theoretically, therefore, there are values of n_e and τ_s for which the actual torsional stress is a minimum.

However, because only the natural frequency of the spring n_e and the alternating component of the torsional stress τ_s can be reliably calculated, they should be chosen as large as possible so that the parts of eqs. (10) which represent the influence of oscillation are kept small. Only harmonics of a higher order, and consequently with a smaller amplitude, then occur, and the actual stress τ_{ac} is approximately equal to τ_s.

An increase of n_e can be effected, for instance, by reducing the number of effective coils.

Another means of reducing the actual stress is the reduction of the clearance between cam and follower because the amplitudes of the harmonics rather decrease, if there is clearance, with $(1/\mu)^2$, i.e., slower than indicated above. Springs of outlet valves are breaking more frequently because the high temperatures and the greater wear of the valve seat require a larger amount of clearance. If the harmonic analysis reveals, within the main range of numbers of revolutions, amplitudes of the order of 0·0004 in., the shape of the cam, or even the lift of the valve, should be altered.

A further means of reducing the detrimental influence of oscillation lies in the damping. Until now, the only successful way was to wind the spring with varying pitch, making the pitch of the last coils smaller. When the spring is compressed, the last coils touch each other, and the linear characteristic, and with it the condition for a harmonic oscillation is lost.

Research and measurements further showed that inaccuracies in manufacture, and the elasticity of the valve mechanism, tend to increase the amplitudes of the harmonics of the valve lift curve. It may, therefore, be advisable to check the accuracy of the cams. It has been found that the deviation of the valve lift from

the theoretical value should not exceed ± 0·004 in., and that the difference of the deviations should be less than 0·0016 in. for a 5-degree rotation of the cam.

An investigation into the dynamics of the valve motion showed that the discontinuity in the first and second derivatives (relating to speeds and accelerations) of cams composed of circular arcs and straight lines were causing noise and increased wear. High-speed engines, therefore, have lately been making wider use of valves with automatic elimination of clearance, so that the motion commences and terminates with almost zero velocity, and further developments suggest that the shape of the cams should conform to an analytical function.

All previous considerations were based on the simplified assumption that the shaft rotates uniformly. It will be shown that this assumption is not always justified, and the influence of a small periodic oscillation will be investigated.

The position of the cam may be defined by the angle α, the angular velocity of the cam ω [sec^{-1}], t the time in seconds, $\nu\omega$ the frequency of oscillation [sec^{-1}], a_ν and b_ν the components of its amplitude, and $\nu = 1, 2, 3$, etc. Then

$$\alpha = \omega t + a_\nu \sin \nu\omega t + b_\nu \cos \nu\omega t \quad .. \quad (11)$$

The valve lift x is a periodic function of the angle α, and can therefore be expressed in the form of a Fourrier's series :

$$x = \sum_{\mu=0}^{\mu=\infty} A_\mu \cos \mu\alpha + \sum_{\mu=0}^{\mu=\infty} B_\mu \sin \mu\alpha \quad .. \quad (12)$$

where μ is the order of the harmonics of the valve lift curve, and A_μ and B_μ the components of their amplitudes.

As a_ν and b_ν are small, eq. (11) leads to the approximate relation

$$\cos \mu\alpha = \cos \mu\omega t - \sin \mu\omega t\,(\mu a_\nu \sin \nu\omega t + \mu b_\nu \cos \nu\omega t)$$
$$= \cos \mu\omega t + \tfrac{1}{2}\mu a_\nu [\cos (\mu + \nu)\,\omega t - \cos (\mu - \nu)\,\omega t]$$
$$- \tfrac{1}{2}\mu b_\nu [\sin (\mu + \nu)\,\omega t + \sin (\mu - \nu)\,\omega t] \quad .. \quad (13)$$

Similarly,

$$\sin \mu\alpha = \sin \mu\omega t + \tfrac{1}{2}\mu a_\nu [\sin (\mu + \nu)\,\omega t$$
$$- \sin (\mu - \nu)\,\omega t] + \tfrac{1}{2}\mu b_\nu [\cos (\mu + \nu)\,\omega t$$
$$+ \cos (\mu - \nu)\,\omega t] \quad .. \quad .. \quad .. \quad (14)$$

By combining eqs. (13) and (14) with (12) we obtain

$$x = \sum_{\mu=0}^{\mu=\infty} \left\{ A_\mu \cos \mu\omega t + B_\mu \sin \mu\omega t + \frac{\mu}{2} [a_\nu A_\mu + b_\nu B_\mu] \cos (\mu + \nu)\,\omega t - \frac{\mu}{2} [a_\nu A_\mu - b_\nu B_\mu] \cos (\mu - \nu)\,\omega t - \frac{\mu}{2} [b_\nu A_\mu - a_\nu B_\mu] \sin (\mu + \nu)\,\omega t - \frac{\mu}{2} [b_\nu A_\mu + a_\nu B_\mu] \sin (\mu - \nu)\,\omega t \right\} \quad .. \quad (15)$$

Resonance of the spring occurs if the natural frequency of the spring ω_e is equal to the frequency of the exciting impulses. According to the classical theory (uniformly rotating cam shaft), $a_\nu = 0$, $b_\nu = 0$:

$$\mu\omega = \omega_e. \quad .. \quad .. \quad (16a)$$

If the cam shaft is oscillating, resonance also occurs for

$$(\mu + \nu)\,\omega = \omega_e \quad .. \quad .. \quad (16b)$$
$$(\mu - \nu)\,\omega = \omega_e \quad .. \quad .. \quad (16c)$$

If the number of revolutions of the cam shaft n [min^{-1}] is introduced instead of the angular velocity ω,

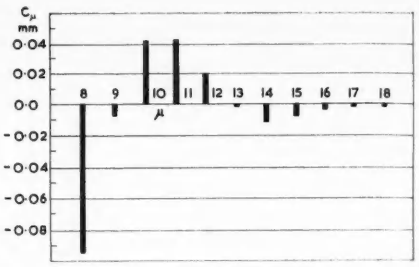


Fig. 3. **Amplitudes of an analysed valve lift curve of a harmonic cam.**

and similarly n_e [min^{-1}] instead of the natural frequency of the spring ω_e, and if, further, n_e/n is assumed to be an integer, the eqs. (16) lead to the order of the harmonics which excite an oscillation of the spring

$$\mu = \frac{n_e}{n}, \quad \mu = \left| \frac{n_e}{n} - \nu \right|, \quad \mu = \frac{n_e}{n} + \nu. \quad (17a, b, c)$$

Equation (17b) shows that also harmonics of a lower order than those according to the classical theory eq. (17a) cause resonance.

Fluctuation in the rotation of the cam shaft may be caused by pitch errors of the gears, or by fluctuation in the rotation of the crankshaft. The latter influence prevails where the crankshaft is in resonance due to torsional oscillations.

In that case, the exciting frequency νn is equal to the natural frequency of the shaft, or $\nu n = n_E$, and eq. (17) leads to

$$\mu = \frac{n_e}{n}, \quad \mu = \frac{|n_e - n_E|}{n}, \quad \mu = \frac{n_e + n_E}{n}. \quad (18a, b, c)$$

Equation (18b) makes it obvious that the order of the harmonic which excites an oscillation of the spring is lower, the smaller the difference between the natural frequencies of spring and shaft. This indicates that spring and shaft should be so designed as to prevent their two frequencies from approaching each other too closely. Of the natural frequencies of the shaft, the frequency of the second mode of vibration is mainly to be considered.

If the number of revolutions of the engine N [min^{-1}] is used instead of that of the cam shaft ($n = N/2$), and if $n_E/n = \lambda$ is an integer (λ is the order of the harmonic of the tangential component of the piston force corresponding to $N\lambda$ revolutions of the motor), we obtain

$$\mu = \frac{2n_e}{N}, \quad \mu = \left| \frac{2n_e}{N} - 2\lambda \right|, \quad \mu = \frac{2n_e}{N} + 2\lambda. \quad (19a, b, c)$$

In the case of strong resonance oscillations, torsional oscillations are also caused in the neighbourhood of $N\lambda$, and it may be assumed that

$$N = (0{\cdot}9 \text{ to } 1{\cdot}1)\, N\lambda. \quad .. \quad (20)$$

The influence of a non-uniform rotation of the cam on the oscillation of the spring may be demonstrated by an example from practice.

The springs of an 8-cylinder Diesel engine, running at about 350 rpm, were mostly cracking in the first coil. The natural frequency of the second mode of vibration was $N_E \triangleq 6000$/min. The natural frequency of the spring was $n_e \triangleq 5420$/min. The diameter of the spring was 6 mm, the stresses due to the basic load were $\tau = 2810$ kg/cm^2, and $\tau_s = 900$ kg/cm^2, i.e., they

were chosen in accordance with Fig. 2.

According to the classical theory eq. (19a), we obtain the order of the harmonics for

$$N = 339 \quad 350 \quad 362 \quad \text{min}^{-1}$$
$$\mu = 32 \quad 31 \quad 30$$

Harmonics of about the 30th order could not have caused breaking of the spring, and yet all pointed to resonance oscillation as the cause. The speed of the engine, for $\lambda = 17$, is $N_{17} = 353/\text{min}$; for $\lambda = 16$ (the main resonance oscillation), it is $N_{16} = 375/\text{min}$.

According to eq. (19b), there are also very effective harmonics of lower orders :

$$N = 339 \quad 350 \ \text{min}^{-1}$$
$$\mu = |32 - 34| = 2 ; \quad |31 - 34| = 3 ;$$
$$\mu = |32 - 32| = 0 ; \quad |31 - 32| = 1 ;$$
$$N = 362 \ \text{min}^{-1}$$
$$\mu = |30 - 34| = 4 ;$$
$$\mu = |30 - 32| = 2.$$

This explains the strong oscillations of the spring which lead to its destruction, even if the fluctuations in the rotation of the camshaft were only small ; similar circumstances were probably the reason of many a breakage which could not hitherto be explained.

GERMANY

The Drilling of Polygonal Holes

By H. H. FINKELNBURG. (From *Werkstatt und Betrieb*, Vol. 83, No. 8, August, 1950, pp. 359-360, 7 illustrations).

POLYGONAL blind holes are often required in engineering practice, and the usual methods of producing them are unsatisfactory because they are very cumbersome. The development of a suitable drilling process by which polygons of practically straight sides can be generated is, therefore, of interest.

The principle of the process can be seen in Fig. 1. The cutter is given, in addition to its axial rotation, an eccentric motion, so that it traces out a polygon. The two rotations are in such relation that when the cutting edge is at the centre of one side, the axis of the drill is farthest away from that side, while for a corner, the axis is at its nearest. From this it follows that the rotations must be in opposite senses, and the sum of the angular displacements, corresponding to a cutting path from the middle of one side to a corner, must be 180 degrees (Fig. 2). The magnitude of the relative rotations can be calculated from the given number of sides n. The central angle of one side of a polygon is $360/n$ degrees. The angular path from the middle of a side to the corner is $180/n$, and the corresponding angular rotation of the drill axis is $(n-1)\ 180/n$. The number of cutting edges z is determined by the fact that when the drill axis has revolved by $360/n$ degrees, the next cutting edge must have reached the centre of the side (Fig. 1). To this angle there corresponds a displacement of the cutting edge by $360/n(n-1)$ degrees, and hence $z = n - 1$, i.e., the number of cutting edges is one less than the number of sides of the polygon. A smaller number may be used, but is disadvantageous on account of the unbalance of lateral loads.

The geometrical relations may be deduced by reference to Fig. 3. Let a be the length of a side. All other data will be given in terms of a, the numerical tables being based on $a = 1$. The radial distance of a side is g, where

$$g = \frac{a}{2 \tan (180/n)}$$

The diagonal length of a polygon is

$$f = \frac{a}{\sin (180/n)}$$

Let the radius of the eccentric movement be r_e and the radial distance of a cutting edge from the tool-axis r_w.

The tool has two limiting positions: (1) The nearest point is the centre of one side. Then $r_w = g + r_e$. (2) The farthest point is a corner. Then $r_w = f/2 - r_e$. If the cutter is to pass through both limiting points accurately, r_e must be given by the two equations above, i.e.,

$$r_e = \frac{f - 2g}{4} \qquad \ldots \quad \ldots \quad \text{(i)}$$

This is the maximum permissible value of r_e. In practice, the values used are always smaller.

Numerical values of z, g, f and r_e are given in Table I. The value of r_e must be such as to permit each cutting edge to trace out a substantially straight path at a distance g from the centre of the polygon.

Fig. 1. **Three-fluted tool in a square hole. One cutting edge is at the centre of one side.**

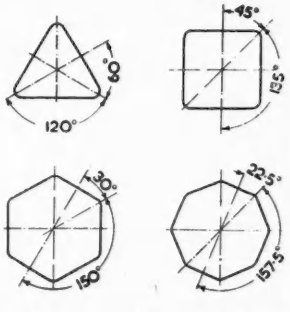


Fig. 2. **Different polygons with angular distance from centre of side to corner and corresponding angular travel of drill axis.**

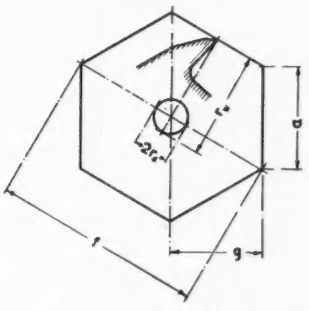


Fig. 3. **Symbols used in text.**

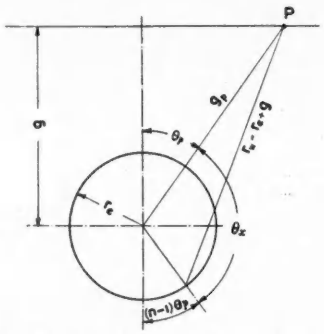
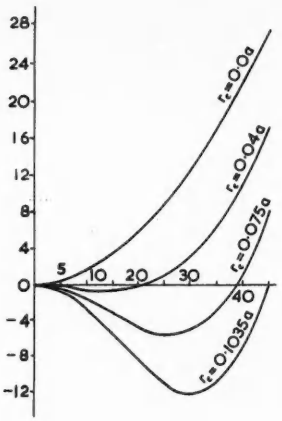


Fig. 4 (above). **Geometry of an arbitrary point P on the cutting path.**

Fig. 5 (right). **Graph of deviations D, as a function of the angular travel of the cutter, for various values of r_e. Square hole.**



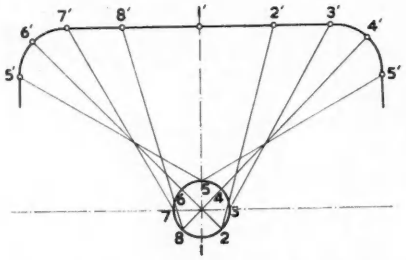


Fig. 6. **Construction of cutting trajectory for a square hole, for $r_e = 0{\cdot}075a$.**

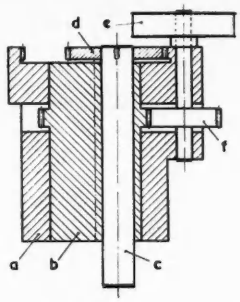


Fig. 7. **Schematic arrangement of the eccentric drive.**

(a) Fixture with internal gear ;
(b) sleeve with eccentric hole ;
(c) drill spindle rotatable in (b) ;
(d) planetary gear for drill spindle drive ;
(e) driving pulley ;
(f) gear driving sleeve (b).

Referring to Fig. 4, if at any point P the generated path is to coincide with the required straight line, the radius r_e is given by the application of the cosine rule

$$r_e = \frac{g\,(1 - \cos^2 \theta_x)}{2 \cos \theta_x\,(\cos \theta_x - \cos n\,\theta_x)}$$

Table II gives the dependence of r_e on θ_p for the case $n = 4$.

The deviation D of a cutting path as determined by r_e, from the required straight line can now be calculated (Fig. 4). It is given by

$$D = \frac{g - g_p \cos \theta_p}{g} 100 \quad \text{[per cent]}.$$

TABLE I. NUMERICAL VALUES OF z, g, f, AND r_e FOR VARIOUS POLYGONS.

n	z	g	f	r_e	Gear ratio drill to eccentric
3	2	0·288	1·155	0 — 0·145	1·5
4	3	0·500	1·41	0 — 0·1035	1·33
5	4	0·688	1·7	0 — 0·081	1·25
6	5	0·866	2·0	0 — 0·067	1·20
8	7	1·21	2·61	0 — 0·0475	1·143

All values refer to $a = 1$.

TABLE III. DEVIATION OF TRAJECTORY FROM A STRAIGHT LINE FOR VARIOUS VALUES OF r_e. SQUARE HOLE.

θ_p in degrees	Percentage Deviation D			
	$r_e = 0{\cdot}000$	$r_e = 0{\cdot}04$	$r_e = 0{\cdot}075$	$r_e = 0{\cdot}1035$
0	0·0	0·0	0·0	0·0
5	0·4	— 0·1	— 0·2	— 0·6
10	1·5	— 0·4	— 1·4	— 2·6
15	3·4	— 0·2	— 3·2	— 5·2
20	6·1	0·0	— 4·6	— 8·4
25	9·4	1·0	— 6·0	—11·0
30	13·4	2·0	— 5·2	—12·6
35	18·1	6·6	— 3·2	—11·2
40	23·4	11·6	1·2	— 7·0
45	29·3	18·0	8·0	0·0

Here, however, g_p is calculated not from g, but from r_e and r_w :

$$g_p = -r_e \cos n\theta_x + \sqrt{r_e^2 \cos^2 n\theta_x + g^2 + 2r_e g}$$

The error D for $n = 4$ for different values of r_e is given in Table III, and is represented in Fig. 5. The limiting cases for $r_e = 0$ and r_e as given by eq. (i) are also shown. It is seen that for the example given, $r_e = 0{\cdot}075$ yields the best results, as the deviations are evenly distributed.

The geometrical construction of the cutting path for the case $n = 4$ and $r_e = 0{\cdot}075$ is shown in Fig. 6. A circle of radius $r_e = 0{\cdot}075a$ is drawn about the centre of the hole, and its circumference, divided into 8 equal parts, marked 1 to 8, with primes for the corresponding points on the trajectory. The distance $1 - 1'$ is $g + r_e$, i.e., $0{\cdot}575a$ in the example. From 2 a radius is drawn at an angle of 15°, from 3 at 30°, from 4 at 45°, etc., and all radii are made equal to $g + r_e$.

Fig. 7 shows schematically a suitable arrangement of the eccentric drive. As the rotations are opposite, the angular travel of the cutting edge must always be greater than that of the drill axis, in fact $n - 1$ revolutions of the axis correspond to n revolutions of the cutter. From this it follows that the gear ratio of the spindles must be $n/(n - 1)$.

Very accurate polygonal holes can be drilled by means of this arrangement, and with a suitable choice of r_e, the rounding off of the corners may be made negligibly small, so that the holes are suitable for all engineering purposes.

TABLE II. VALUES OF r_e GIVING A DEVIATION $D = 0$ FOR VARIOUS POINTS ON THE TRAJECTORY.

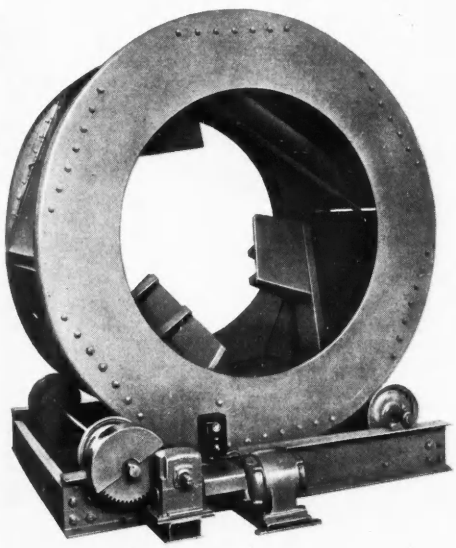
θ_p in degrees	1	5	10	15	20	22·5	25	30	35	40	45
r_e for $a = 1$ ..	0·03261	0·03375	0·035	0·0392	0·04064	0·0429	0·0456	0·0528	0·0635	0·079	0·1035

New Materials, Processes and Equipment

Tester for Loaded Containers.

L. O. Koven & Brother, Inc., Jersey City, N.J., are manufacturing a fatigue tester for the testing of loaded paperboard, fibreboard and wooden shipping cartons and boxes.

The testing machine has a vertically mounted revolving drum, consisting of a hexagonal-shaped testing chamber supported by two flanged steel heads mounted on an I-beam base. It is built in two models for handling small-to-medium and medium-to-large size containers, respectively. Model A is capable of handling containers up to 20 in. × 20 in. × 20 in. in size and not exceeding 250 lb in gross weight. Model B is capable of handling containers having a length of over 20 in. and up to about 72 in., and weighing up to 1000 lb gross.

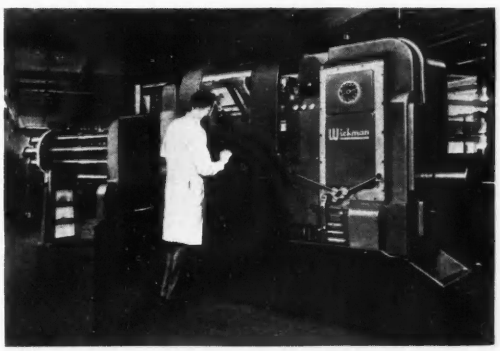


Tests will indicate (1) the ability of a container to withstand various shocks and impact stresses simulating those which may be expected in handling and shipping, (2) the ability of packing and carton designs to protect the contents when subjected to such shocks and stresses, and (3) will give a comparison of different designs of containers of the same size and carrying the same load.

Four and Six-Spindle Bar Automatics.

The new series of four-spindle and six-spindle bar automatics is designed by A. C. Wickman Ltd., Coventry, on basically similar lines to their successful five-spindle range, but is of much larger and heavier construction, embodying many improvements and refinements in anticipation of the heavy work such machines are required to perform.

They offer particular advantages to the Ball and

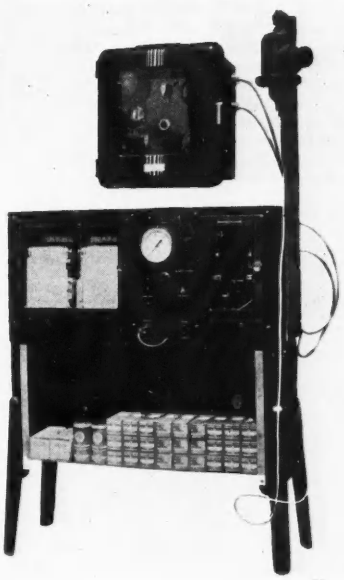


Roller Bearings Industry, Automotive Industry, and Textile Machine Manufacturing Industry, where heavy metal-removal, extreme accuracy and fast output on long- or short-run batches are frequently required.

The incorporation of the Wickman patent autosetting mechanism which effects alterations to tool feed strokes and bar feed without cam-changing, yet leaves unaltered the full fast approach stroke, simplifies setting-up, reduces change-over time, and dispenses entirely with costly interchangeable cams.

Electronic Flame Control Instrument.

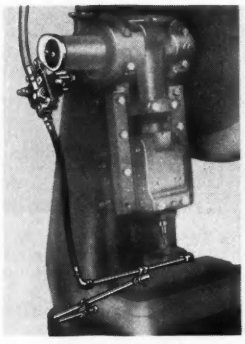
A new model instrument that makes the operation of Bessemer converters a simple matter with high technical accuracy in determining the end point and controlling the carbon. This instrument enables the operator definitely to determine the silicon, manganese and carbon periods and forewarns the operator of impending



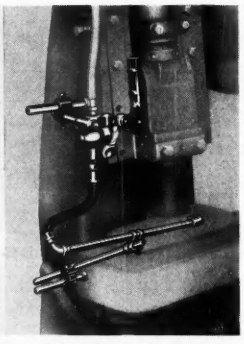
manganese boils, thus reducing loss of metal and time. The correct end point is accurately established, eliminating excessive iron oxide. The instrument is also valuable when it is desired to stop the blow before the end point to retain some carbon content.

Ready-To-Fit Ejection Sets.

Air ejection, using an intermittent-timed blast of air to replace some mechanical or manual movement, increases the rate of production on all presswork. A. Schrader's Son, Birmingham, have introduced two standard ejection sets, one a cam-operated assembly and the other ram-operated.



Cam-operated ejection set

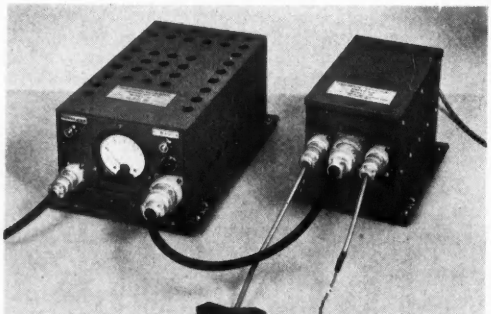


Ram-operated ejection set

These are installed so that their working becomes part of the cycle of operation of the machine. In the cam-operated set an adjustable cam operates a blow valve with suitable roller-type lever, while in the ram-operated set the air blast is adjusted by the position of the slotted roller tripper along the ram which trips a blow valve with an angle-type lever. An adjustable air director with fitted hose completes the installation directing a quick blast of air at airline pressure.

Dynamic Pressure-Measuring System.

Phase and amplitude errors rising from flexible-tube connection of pressure cells used in dynamic measurement are eliminated in the flush-mounted cells developed by Sierra Electronic Corp., San Carlos, Calif., by elimination of the tubing connections themselves. Cells are mounted directly on the surfaces upon which the pressures to be measured impinge. Phase accuracy throughout is better than $\pm$ 0·2 degrees. Accelerations encountered on vibrating or oscillating surfaces are negligible in effect. Because of these characteristics, cell outputs can be combined electrically for measurement such as lift or hinge-and pitching-moments of ailerons. With this technique, complicated calculations are avoided.



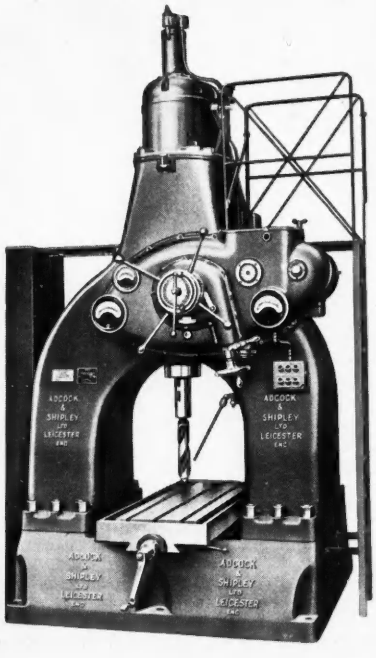
Related equipment to provide for driving standard oscillograph elements from cell outputs includes carrier-frequency bandpass amplifier, oscillator, and power supply. These are housed in two small containers as illustrated.

This equipment is particularly applicable to the measurement of instantaneous aerodynamic forces of the types encountered in flutter-, transient-, and gust-studies in wind tunnels, or in flight. In addition, a wide range of non-aeronautical uses is opened up by the simplicity, small size, and non-clogging character of the flush-mounted cells.

Heavy Duty Drill Testing Machine.

This machine was designed by Adcock & Shipley Ltd., Leicester, for the testing of twist drills up to 3 in. in diameter. The method of testing usually employed is to drill a series of holes in a material of known specification at set speeds and feeds until eventually the drill becomes blunt, which can be judged from the amount of power consumed.

The high stresses set up by this type of testing can only be covered with a " portal " type machine as shown



on the accompanying photograph. In addition to following this style of design, the manufacturers have been very careful to arrange the shape and sections of the main castings for maximum rigidity and minimum deflection. On test, it was found that the maximum deflection when using 40 hp was 0·002 in. measured from the table top to the portion of the main casting carrying the quill.

CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

FLOW OF FLUIDS

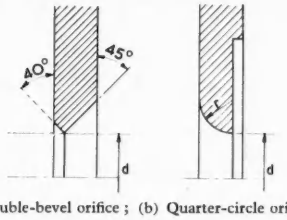
The Measurement of Fluid Flow at Low Reynolds Numbers

By A. SCHLAG. (From *Revue Universelle des Mines, Belgium*, 9th Series, Vol. 6, February, 1950, pp. 45-47, 4 illustrations.)

FLUID flow measurements by means of orifices or Venturi meters are based on the formula

$$Q = k \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gH} = \frac{k}{\sqrt{1-m^2}} a_2 \sqrt{2gH} = K a_2 \sqrt{2gH},$$

where H is the pressure difference between two given standard sections of the arrangement, a_1 the full pipe cross-section, a_2 the restricted cross-section of the measuring device, m the ratio a_2/a_1, k and K coefficients particular to the device employed. The coefficient K was widely used on the Continent, but the International Standard Organisation has now recommended the general adoption of the coefficient k normally used in Anglo-Saxon countries. The coefficient k (as also K) is not constant, but varies with the Reynolds number, especially at low Reynolds numbers. Different measuring devices have been proposed, for which k only varies within narrow limits, and the I.S.O. has finally recommended to the National Standard Institutions the adoption of the two standard orifices shown in Fig. 1.



(a) Double-bevel orifice ; (b) Quarter-circle orifice.

Fig. 1.

For the *double-bevel orifice* with $m = 0{\cdot}121$, the coefficient k has been found to be satisfactorily constant over a range of Reynolds numbers R_e from 50 to 30,000[1]. At $R_e = 35{,}000$, however, a sudden variation of 1 per cent occurs[2]. Check tests at Liège University, reported in this paper, confirmed that k = const. = 0·741 for R_e from 700 up to 3000. For $R_e > 3000$, k first decreases slightly, then increases again to 0·748 when R_e = 20,000 to 30,000. On the strength of ample test experience[3], German standards[4] for the *quarter-circle orifice* are based on the following data, although a cautionary note attached to the standards still recommends special calibration tests :

Orifice data	m	0·0506	0·16	0·25	0·36	0·391
	r/d	0·10	0·112	0·135	0·208	0·285
Mean value of k		0·769	0·782	0·804	0·842	0·859
Usable for R_e =		700 to 56,000	650 to 140,000	330 to 240,000	300 to 270,000	370 to 150,000

Constant values for k have been confirmed[2] for m = 0·05 and $R_e < 2000$, as well as m = 0·49 and $R_e < 20{,}000$, but it has also been suggested[1] that this type of orifice does not supply reliably constant values of k for $R_e > 100{,}000$. Tests at Liège with an orifice of m = 0·25, r/d = 0·135, and R_e = 2000 to 100,000, led to a mean value of k = 0·808, sufficiently close to the German standard value. Further test series are suggested so that present standards may be extended.

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(2) FERROGLIO, *L'Energia Elettrica*, No. 19, 1942.
(3) KOENNECKE, *Forschung auf dem Gebiet d. Ing. Wesens*, May/June 1938.
(4) *VDI. Durchfluss-Messregeln*, 6th Ed., DIN 1952, Berlin 1948.

INTERNAL COMBUSTION ENGINES

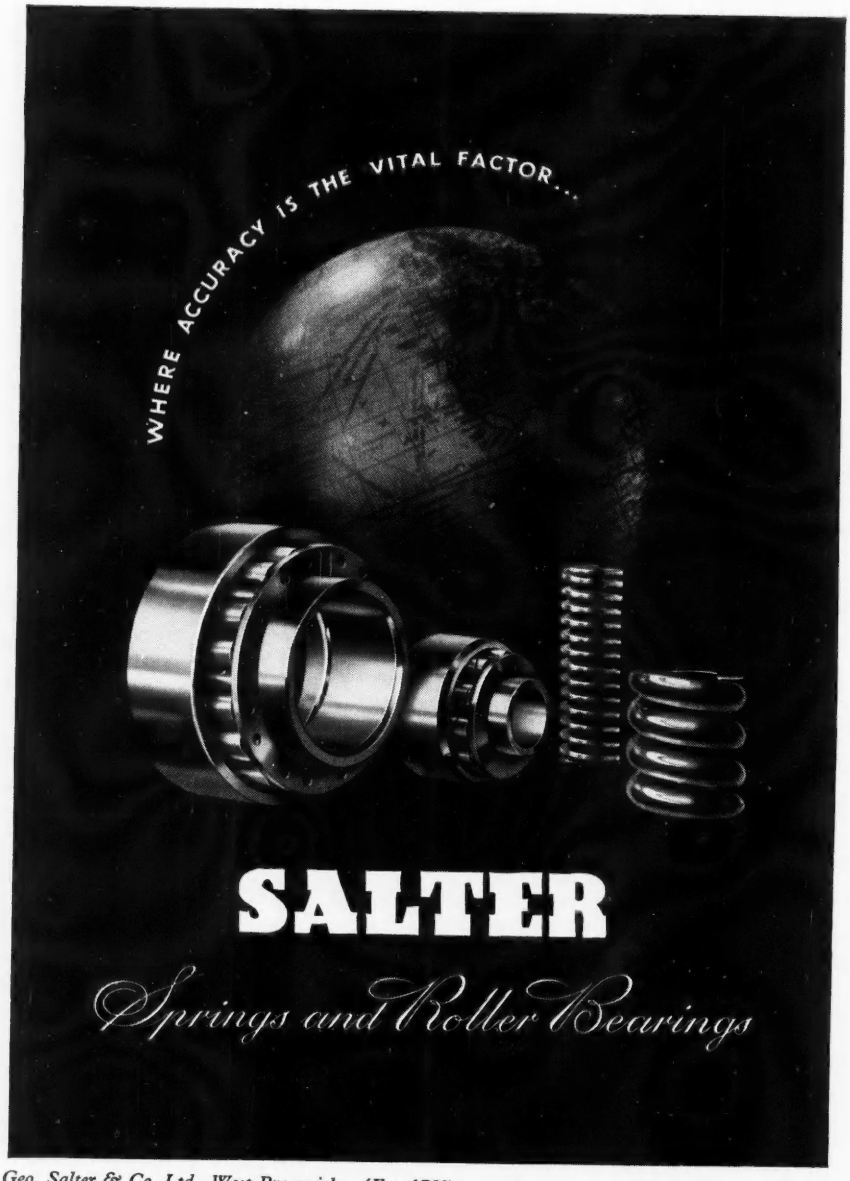
No Harmful Pre-Ignition from Lead Deposits

By A. HUNDERE. (From *Automotive Industries, U.S.A.*, Vol. 103, No. 5, September 1, 1950, pp. 50, 76, 78, 80 and 83, 2 illustrations.)

A SERIES of tests was carried out on an air-cooled aircraft engine cylinder of recent design, in order to determine whether the lead deposits left by tetraethyl lead, used to improve the anti-knock quality of the fuel, are the cause of harmful pre-ignition effects.

A 500-hour test was first made, using aviation alkylate containing 6 millilitres of tetraethyl lead per U.S. gallon, under conditions conducive to the formation of deposits (i.e., low cylinder head temperatures, low power and lean mixtures). Large amounts of combustion chamber deposits were formed, but there were no indications of pre-ignition. Even with considerable deposits, pre-ignition could only be obtained by rapidly increasing the power level of the engine. Cylinder head temperature was unchanged and rate-of-pressure-change diagrams obtained with a Calstan indicator showed that the maximum surface ignition advance was 30 deg. BTDC, or 5 deg. less than the maximum-power spark advance for normal operating conditions. Similar results were found with benzene and diisobutylene.

Tests with various lubricating oils showed that destructive pre-ignition (defined as a pre-ignition capable of raising the head temperature by 100° F or more) could only be obtained with metal-containing compounds, and then only when the oil consumption was high. Variation of the sulphur content had no detectable effect. Most of the oil compounds were introduced in the form of a metal naphthenate. It was found that incipient pre-ignition, with about 20 deg. surface ignition advance BTDC, could be expected with any fuel or oil constituents that leave deposits with a melting point above 2000° F ($PbSO_4$ and Cu_2O), and destructive pre-ignition, with surface ignition advance of 60 deg. BTDC or more, for constituents with melting points exceeding 2650° F. ($CaSO_4$, Fe_2O_3, SiO_2, ZnO, BaO, Al_2O_3 and CaO). However, no pre-ignition results unless the deposits build up to a sufficient thickness to create poor heat-conductivity conditions with increased temperatures, and unless the deposits are structurally strong enough to maintain pre-ignition temperatures. Combustion products with a low melting point may also cause pre-ignition by corroding the metal surfaces of the combustion chamber so as to oxidise and form pre-ignition deposits. Engine tests are therefore necessary to determine whether a given material will cause pre-ignition from combustion chamber deposits. Metals present in the oil from normal engine wear are insufficient in quantity to cause harmful pre-ignition.



Geo. Salter & Co. Ltd., West Bromwich. (*Est. 1760*)

M-W.157

The lead fouling of sparking plugs considerably hampered the study of pre-ignition and should be given serious consideration. Sparking plug designs with properly evaluated pre-ignition ratings may help to overcome this difficulty, without requiring a reduction in the lead content of the fuel or special design of the scavenger.

MATERIALS TESTING

Hardness Tests Applied to Plastics

By Von E. Kruse. (From *Schweizer Archiv, Switzerland*, Vol. 16, No. 8, August, 1950, pp. 225-243, 13 illustrations.)

Among the numerous hardness test methods suggested in the course of development, the static pressure methods have been prevalent in engineering. Of the latter, the best are those which use diamonds as penetrating bodies and which give geometrically similar images, independently of the depth of penetration. These methods are characterised by very feeble impressions, so that the hardness tests are practically non-destructive. They sometimes enable us even to examine microscopic surfaces.

Among the usual procedures, the Rockwell test is remarkable owing to its economic advantages; the Vickers and Knoop test methods are characterised by their great accuracy, by the fact that the hardness values are independent of the charge applied, and also by the fact that they are expressed in kg/mm^2.

The hardness values obtained by means of the various methods do not, as a rule, agree with each other. There exists a quasi-linear relationship between the hardness values according to Brinell, Vickers and Knoop; we must, however, reckon with differences which can amount to as much as 20 per cent, depending on the prevailing test conditions. As to the Rockwell hardness, the latter does not show a linear dependence (proportionally) on the preceding ones, the Rockwell hardness scale being heavily deformed at extremely low and extremely high values.

It will be one of the future tasks to co-ordinate the various test methods to a greater extent, particularly their underlying definitions of hardness, without, however, losing sight of the advantages peculiar to each system. Furthermore, it would be advisable to deal separately with the cases of plastic deformation and those of elastic deformation; this would enable us to draw further inferences from the results of the hardness tests.

The optical properties of plastic materials require special devices for the hardness tests. In the case of rigid plastic materials, as with metals, it is of no importance whether or not the elastic deformation is taken into account. It is only in the case of plastic materials of high elasticity that it is necessary to define the hardness in some other way than usual, if we wish to obtain values which make sense and if we wish to compare them with those obtained by means of Brinell, Vickers and Knoop tests.

The hardness tests applied to plastic materials at high temperatures give a good idea of the softening phenomena which then occur. In the case of thermosetting plastics, we thus obtain good indications as to the degree of hardening or the state of hardening of the piece under examination.

ROLLING MILL PRACTICE

On the Use of Cast Iron and Soft Steel for Rolling Mill Bearings

By J. Teindl. (From *Hutnicke Listy, Czechoslovakia*, Vol. 5, No. 3, March, 1950, pp. 97-101, 20 illustrations.)

The author reports on the results of experiments carried out in several factories in Silesia in which cast iron and soft steel bearings were used as replacements of bronze bearings in roll stands. The chemical composition of the cast iron and steels and other relevant test data are given; illustrations included in the paper show scale drawings of the bearings and the stands in which such bearings were used, the bearing surface after their removal from the stands, and the microstructures of the iron and steel used in the experiments. The results obtained show that iron and soft steel are suitable for bearings of hot-rolling stands for fine sheet (thin strip). Mild-steel bearings proved successful in stands with neck diameters exceeding 600 mm, but did not prove suitable for rolls with 530 mm or smaller neck diameters in which sheets of smaller average thicknesses are being rolled. Cast iron proved to be suitable for the top and side bearings of stands for rolling fine-gauge sheet. The life of such bearings depends on the use of a suitable neck lubricant and also on the type of rolling stand.

RUBBER AND RUBBER PRODUCTS

A New Elastic Element

(From *Technische Rundschau, Switzerland*, No. 35, September 1, 1950, pp. 5-6, 6 illustrations.)

The main purpose of elastic construction elements is the absorption of mechanical shocks. The limitations of metal springs (hitherto chiefly employed in this field) lie in difficulty of machining and comparatively slow damping. A satisfactory elastic element should combine sturdiness with effective damping properties. Such an element has been developed by Neidhart in Switzerland. It consists of an axially aligned square tube and rod, with rubber blocks wedged between the internal corners of the tube and the faces of the rod. On applying torsion to the internal rod, the rubber blocks are compressed; thus, the system is equivalent to a torsion spring. The element is remarkably stable under large angular displacements and its elastic properties are variable over a considerable range by suitable dimensioning. It can operate in either direction and can cope with both static and dynamic loads. Due to the great elastic hysteresis effect in the rubber, the damping is almost instantaneous in comparison, e.g., with a leaf spring designed for the same service.

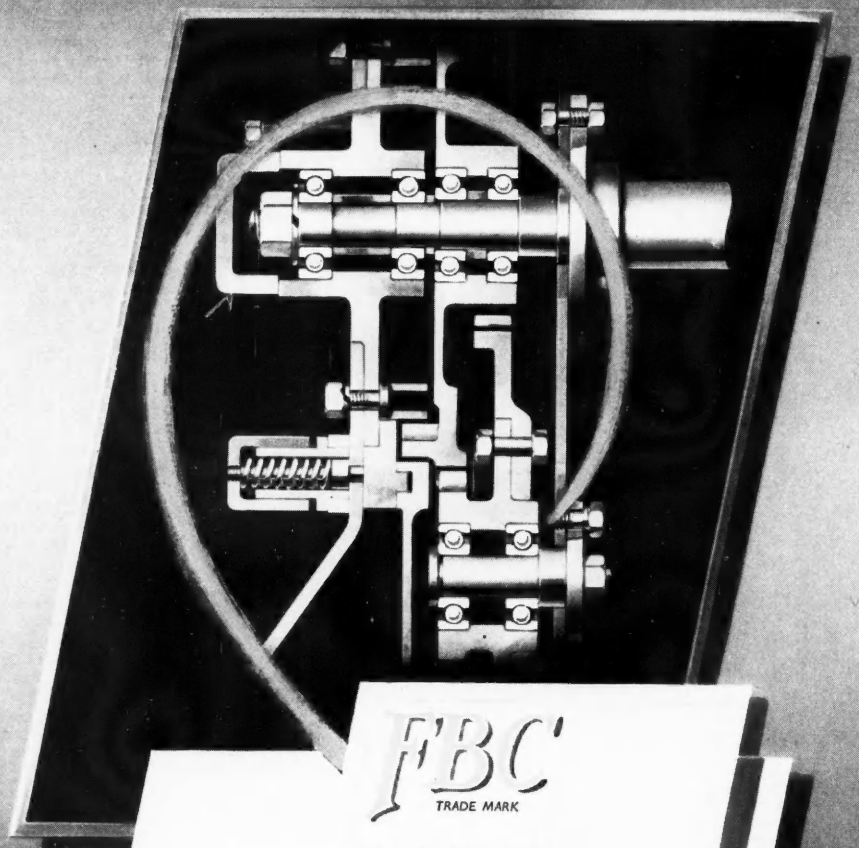
Further advantages of the patented "Neidhart-element" are its low weight, uniform and noiseless functioning (even under water), and the fact that no maintenance is required. Elements employed in vehicles have completed 4 years of satisfactory and trouble-free service. They could be used with advantage for all types of vehicles, conveyor belts, belt drives, seats (e.g., tractor and motorcycle saddles, office chairs, workshop stools), elastic machine couplings etc.

WELDING

Welding of Two Different Steels by Austenitic Electrodes

By J. Weinzettl. (From *Svařování, Czechoslovakia*, Vol. 10, No. 3, April, 1950, pp. 38-46, 15 illustrations.)

The welding problems concerning welding of two different steels are discussed in the paper with particular reference to the use of austenitic electrodes. The Maurer diagram and the equations expressing the effect of the individual alloying elements on the formation of austenite and ferrite, the coefficients for calculation of equivalent values, the Schaefler equation defining the phase limit between alloys of austenitic structure and alloys of a structure of austenite and ferrite, and the graphical solution in the case of multi-layer welds, are discussed. Information is given on the application of these methods to steels and electrodes of Czech manufacture. The results obtained by means of the Maurer diagram for Czech steels and electrodes are checked by analysis of specimens made in the workshops.



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The illustration shows some of the F.B.C. deep-groove bearings on a gang mower made by Thomas Green and Son Ltd.

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NEWS OF THE MONTH

PERSONAL

Mr. Paul Adorian, Assistant Managing Director of Broadcast Relay Services Ltd., has been elected President of The British Institution of Radio Engineers.

Mr. W. A. Ankerson, B.Sc. (Eng.), A.M.I.E.E., has been appointed manager of the dominions division of the Metropolitan-Vickers Electrical Export Co. Ltd.

Mr. D. G. Armstrong, A.R.S.M., B.Sc., A.M.I.M.M., has joined the staff of the Research Laboratories of The General Electric Co. Ltd., Wembley, Middlesex. He is in charge of the Mineral Dressing Group which works on behalf of their Fraser & Chalmers Engineering Works.

Capt. R. G. Arnot, R.N., has been appointed general manager of Rhodesian Alloys Ltd., Gwelo, Southern Rhodesia.

Mr. K. C. Banks and **Mr. J. N. Compton, M.I.Mech.E.,** have been appointed directors of the Yorkshire Engine Co. Ltd., Sheffield.

Mr. J. W. Cartlidge has been elected chairman of the Council of the Zinc Alloy Die Casters, Association, Lincoln House, Turl Street, Oxford. **Mr. E. B. Hill** and **Mr. F. G. Woollard** have been elected deputy chairmen.

Mr. H. Copping, M.I.E.E., has been appointed general sales manager of the Electrical Equipment Division of Newman Industries Ltd., Yate, Bristol. **Mr. E. A. Parr-Dudley, A.M.I.E.E.,** will continue as London sales manager of the Division.

Mr. H. B. Dauncey, works manager of T. H. & J. Daniels Ltd., Stroud, has been appointed director of the company.

Mr. L. Drucquer, M.I.E.E., has been appointed Manager of Home Sales (Plant and Apparatus) of The British Thomson-Houston Co. Ltd., Rugby. **Mr. P. E. Gaze, B.A., A.M.I.E.E.,** has been appointed Manager of the B.T.H. Switchgear Sales Department, Willesden, in succession to Mr. Drucquer.

Mr. R. A. Emerson has been appointed assistant chief engineer of the Canadian Pacific Railway Company.

Mr. Leslie Gamage, Vice-Chairman and Joint Managing Director of The General Electric Co. Ltd., has left England for a five weeks business trip to Canada. His visit will culminate in an address on "Britain's Industrial Recovery," to the Canadian Club, Montreal, on the 30th October, which will be broadcast throughout Canada.

Mr. L. S. Gould, A.M.I.E.E., has been appointed distribution engineer, chief engineers' department of the South-Western Electricity Board, Bristol.

Mr. G. W. Harriman, O.B.E., has been appointed deputy managing director of the Austin Motor Co. Ltd., Birmingham.

Mr. J. Moore-Ogilvie, late of Delapena & Son Ltd., Cheltenham, has been appointed publicity manager of High Duty Alloys Ltd., Slough.

Mr. A. J. Palmer, C.B.E., has been elected a director of Vickers Ltd., Vickers House, Broadway, London, S.W.1.

Mr. W. E. W. Petter has been appointed deputy managing director of Folland Aircraft Ltd., Hamble, Hants.

Mr. T. W. Pollock has been appointed managing director of Penman & Co. Ltd., Caledonian Ironworks, 64 Strathclyde Street, Glasgow.

Mr. J. S. Ramsden, M.I.E.E., has relinquished his seat on the Board of the British Thomson-Houston Co. Ltd. He is remaining with the company in a consultative capacity.

Mr. H. B. Robin Rowell has been elected chairman, and **Mr. J. Ramsay Gebbie,** vice-chairman of the Council of the British Shipbuilding Research Association.

Mr. Maurice Solomon, F.C.G.I., M.I.E.E., is retiring from the Board of The General Electric Co. Ltd. on account of continued ill health.

Mr. W. S. Steel, B.Sc. (Eng.), M.I.E.E., A.M.Inst.Mar.E., has been elected a director of The British Thomson-Houston Co. Ltd., Rugby.

Mr. J. H. W. Turner, B.Sc. (Econ.), B.Sc., A.M.I.C.E., has been appointed honorary secretary to The Engineers' Guild, in succession to **Mr. W. A. M. Allan, A.C.G.I., M.I.C.E.,** who relinquished his appointment owing to pressure of professional and private business. Mr. Turner continues as Editor of the Journal.

Captain (E) G. Villar, R.N. ret., Mr. K. C. Barnaby and **Mr. L. L. Holt** have been appointed directors of John I. Thornycroft & Co. Ltd.

Mr. R. E. Winter, A.M.I.Mech.E., has been appointed manager of the Fan Department of Air Control Installations Ltd., Ruislip, Middlesex, in succession to Mr. W. Lee who has left the Company. Mr. Winter has latterly held the position of London Manager of Aerex Ltd.

Mr. J. Reid Young has been appointed a director of S. Smith & Sons (England) Ltd., Waterloo Road, London, N.W.2.

BUSINESS NOTES

B.V.C. Industrial Constructions Ltd., have moved their Offices to Terminal House, 52 Grosvenor Gardens, London, S.W.1.

Brook Motors Ltd., Empress Works, Huddersfield, have moved their London Office to 16-18 Palmer Street, London, S.W.1.

Head Wrightson Aldean Ltd., have changed the name of the Company to Head Wrightson Aluminium Ltd. Sir John Wrightson, Bt., is chairman of the Company. Mr. R. H. Sturges has been appointed director and general manager and Mr. R. W. B. Holland commercial manager.

Electro-Hydraulics Ltd., have formed a subsidiary company, the Conveyancer Fork Truck Company, Liverpool Road, Sankey, Warrington, to market their range of fork trucks.

Heenan & Froude Ltd., Worcester, announce that they have taken over the designs, drawings, patterns, jigs, etc., of the range of Automatic Machines for the Wire and Strip Industry hitherto manufactured by A. W. Macnamara Ltd., Birmingham. Future designs will incorporate the best features of Heenan and Macnamara machines.

A. C. Wickman Ltd., Banner Lane, Coventry, have been appointed Sole Selling Agents throughout the world. All future enquiries for such Automatic Machines should be sent to them or to their Agents overseas. Enquiries for new machines already in the hands of Messrs. Wickman or Messrs. Macnamara will be dealt with as quickly as possible.

Dewhurst & Partner Ltd., Inverness Works, Hounslow, Middlesex, announce the opening of a Branch Office at 118 Nelton Road, West Bridgeford, Nottingham (Telephone Nottingham 88960), to cover the North Midlands area. **Mr. A. Owen,** resident engineer and manager is in charge of this Branch Office.

The Berlin Marketing Council. An Advisory Council has recently been set up with offices in London, Berlin, Frankfurt and Paris to facilitate and increase the volume of trade between West Berlin, Britain and the British Dominions. Official British, American and French support has been secured for the organization which is also sponsored by the Berlin City Authorities.

The work of the Council covers products from drugs to heavy machinery, in addition to materials needed as imports for these industries. Enquiries should be addressed to the Secretary, The Berlin Marketing Council (London), Slough Estate House, 16 Berkeley Street, London, W.1.

Export Control of Machine Tools. The Board of Trade have made an order which came into force on October 6 under which the export of any power operated metal working machine tools is made subject to licence. Export to Commonwealth countries and to the United States are exempt from the licensing procedure.

We can help you to solve your worries about components—and quickly too. The Brailey process of hard chromium and heavy nickel electro-deposition hardens without distortion and will give a new lease of life to parts destined for salvage. Ask for our technical representative to call—he will be pleased to assist and advise you in every way.

32-page booklet covering many applications sent on written request to responsible enquirers.

BRAILEY ELECTROPLATERS LTD.
ESTABLISHED 1872
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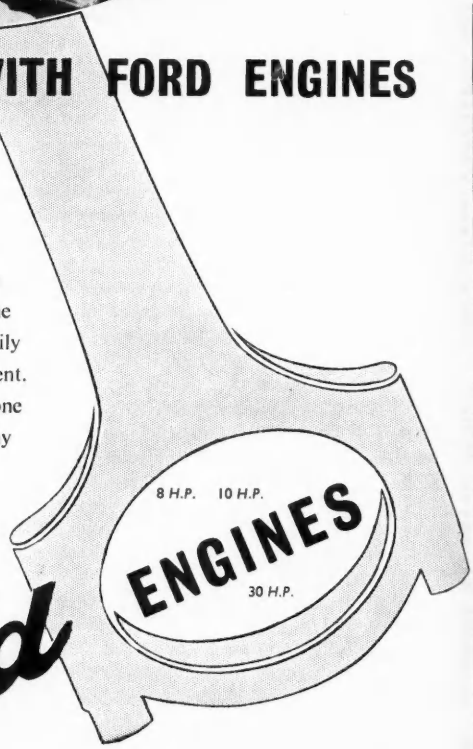
GETTING DOWN TO IT—WITH FORD ENGINES

Ford engines are real stayers. They stay on the job all the time and overtime, giving continuous trouble-free service under the toughest conditions. Ranging from 23 to 85 b.h.p. (there is also a Petrol/Vaporising Oil Engine for particularly heavy duty) these thrifty units are readily adaptable for a very wide range of industrial equipment. Cranes, air compressors, generating sets, winches, stone crushers, road rollers — these are only a few of their many uses. *Our Industrial Unit Department is freely at the disposal of manufacturers of Industrial Equipment for the full discussion of their particular problems.*



Ford

FORD MOTOR COMPANY LTD., DAGENHAM, ESSEX

FOR INDUSTRIAL EQUIPMENT

Relaxation of Canadian Import Restrictions. The Board of Trade wish to remind Exporters that all remaining Canadian import prohibitions and quota restrictions will be removed with effect from January 2, 1951.

Albright & Wilson Ltd. and the Dow Corning Corporation of America announce the formation of a new Company, Midland Silicones Ltd., which assumed, on September 25th, all the activties previously undertaken by the silicone department of Albright & Wilson Ltd.

The new Company has come into being to provide a larger sales organization and improved technical service for silicone products, whose unique properties have already established them in a wide range of industrial processes. For the time being the new Company will continue to market silicone products imported from America and manufactured by the Dow Corning Corporation. In the near future, however, when Albright & Wilson Ltd. begin manufacture in England, they will act as selling agents for the English Company, and the shortages imposed by restrictions on dollar imports will be entirely overcome.

The directors of Midland Silicones Ltd. include members of both the English and American parent companies, among them Mr. J. C. Christopherson, sales director of Albright & Wilson Ltd., and Mr. K. A. M. Barton, who joins the board as sales director of the new Company.

Aluminium Alloy Castings Containing Nickel. Another addition to the many technical publications issued by The Mond Nickel Company, Limited, is their new publication on aluminium alloy castings.

Based on the paper presented by Frank Hudson, F.I.M., to the congress of The American Foundrymen's Society in May of this year, it deals with all aspects of castings in these alloys, including early developments, recent metallurgical practice and modern production methods.

A tabulated summary of the many alloys available, combined with a wealth of illustrations showing foundry technique, etc., makes this publication valuable to engineers and designers in all industries. Copies may be obtained, free of charge, upon application to: The Mond Nickel Company, Limited, Sunderland House, Curzon Street, London, W.1.

"METAMIC"—A NEW ENGINEERING MATERIAL.

The Morgan Crucible Co. Ltd., have for some time been actively engaged in the development of metal-ceramic materials, and have registered the Trade Mark "Metamic" to cover their products of this type.

Modern methods and techniques have created a growing, and as yet unfulfilled, demand for materials which will operate satisfactorily at temperatures above those at which the present high temperature alloys may be used. Under these severe thermal conditions the conventional ceramics generally fail to combine all the desirable properties such as high strength and resistance to creep and thermal shock. The ideal may be to combine the better features of both metals and ceramics. Considerable interest is therefore being shown in bodies in which metals and ceramics are intimately associated so as to constitute what is virtually a new class of materials.

The Research Laboratories of the Morgan Crucible Co. Ltd., are developing "Metamic" materials to cover a wide range of applications. The use of "Metamic" for turbine blades is one example of the many possible applications for this material, and may enable turbine operating temperatures to be raised to such a degree as to effect a considerable fuel economy.

It must be understood that the numerous combinations of metal, ceramic, and methods of manufacture will permit a wide variation in the properties and fields of use of this new material: thus, for particular uses, one may desire resistance to oxidation, corrosion, erosion, or creep, the formulation being varied to meet these requirements.

DEVELOPMENTS IN NIMONIC ALLOYS.

The Nimonic Alloys were specifically developed to meet the stringent requirements of gas turbine designers for a blade material which, in addition to withstanding high stresses at very high temperatures, would have good resistance to creep. At the time of their introduction, these nickel-chromium alloys were the only materials which would give the properties required in this type of service.

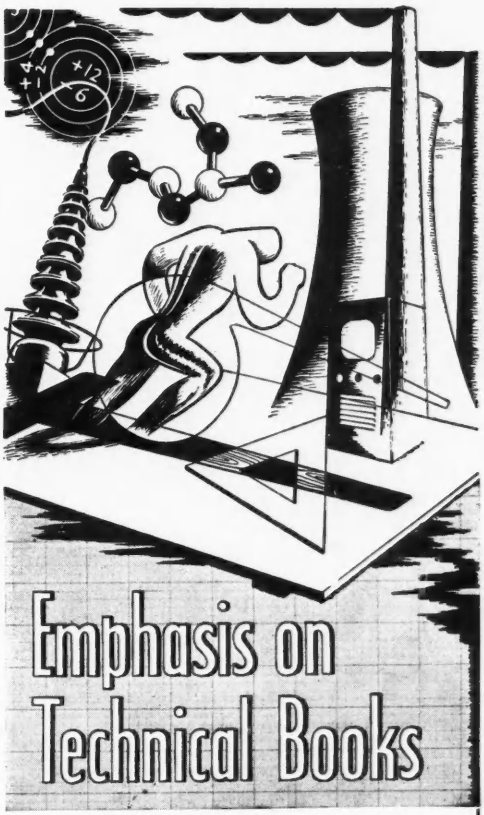
Designers were quick to realise the outstanding advantages offered by these materials for high temperature service and such uses for gas turbines as flame tubes, nozzle guide vanes etc. which were rapidly developed but, in addition, the Nimonic Alloys had a large number of other applications. Materials required for such vital service as turbine blades are made under rigid control and creep tested to meet exacting standard specifications. For other applications where the creep tested material is not required, the alloys are supplied to the same composition but without creep testing.

The development of these uses has resulted in the Nimonic Alloys becoming available in a variety of forms adopted to the specific need of the designer. To assist in the correct choice of the most suitable grade, the alloys have been reclassified. Henry Wiggin & Co., the producers of the Nimonic Alloys, have recently issued a leaflet which summarizes the types available.

TUNGSTEN CARBIDE ROLLS FOR COLD ROLLING OF METALS.

At the Annual Convention of the Association of Iron and Steel Engineers, held in Cleveland, Ohio, from September 26th to 29th, Mr. R. T. Beeghly, vice-president of Metal Carbides Corporation, Youngstown, Ohio, compared tungsten carbide rolls with those made of steel. Following is a summary of Mr. Beeghly's remarks:

A wider use is being made of tungsten carbide rolls for cold rolling all types and analyses of strip steel and non-ferrous metals.



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technical training officers,
and works librarians

who are constantly seeking the newest technical publications will find a quick and competent service at any branch of W. H. Smith & Son. Bookstalls can supply your requirements just as easily as the W.H.S. shops. Each is in daily contact with Head Office in London and your orders, either for single copies or complete works libraries, will be fulfilled within the shortest possible time.

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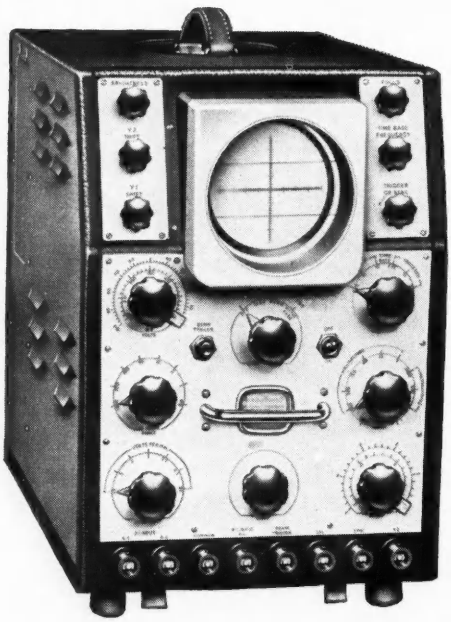
BRANCHES THROUGHOUT THE COUNTRY

THE COSSOR DOUBLE BEAM OSCILLOGRAPHS



Can this Instrument solve a problem for you?

Here are some details of Model 1049 as illustrated:

The Double Beam Tube presents two simultaneous independent traces over the full diameter of a 90 mm. screen, and provision is made for the measurement of both input voltage and time upon the calibrated dials of the instrument. The specification also includes facilities for Time Marking. The Oscillograph is particularly suited for the investigation of very low frequency phenomena and high-speed transients where writing speeds of 45 Km/sec. are attainable, using the Cossor Model 1428 Camera for which a Motor Drive Attachment Model 1429 is available.

Widely different industries are daily finding new uses for the COSSOR Double Beam Oscillograph. Sometimes it provides the answer to an industrial problem of long standing. The tracing and measurement of noise, strain and vibration are typical everyday applications of this versatile instrument which is already helping engineers in industries as far apart as brewing and the manufacture of jet engines. Call on our technical advisory staff if you have a problem. They will quickly let you know whether the Oscillograph can help you.

COSSOR

Double Beam OSCILLOGRAPHS

Please address enquiries to:
A. C. COSSOR LTD. INSTRUMENT DIVISION (Dept. HJ), HIGHBURY GROVE, LONDON, N.5.
Telephone: CANonbury 1234 (30 lines) Cl.21

Over 50 plants now have carbide rolls installed on 2-high, 3-high, 4-high and cluster type mills. Tungsten carbide rolls are produced by hot pressing a mixture of extremely fine powdered tungsten, cobalt and carbon in a graphite mould. The metal powder is compressed under heat and pressure to one-third its original length which produces a structure of unusual density. Carbide rolls have a density of 14·8 compared to 8·6 for steel. Other physical properties include a value of 275,000 psi transverse rupture strength, a tensile strength of 150,000 psi, and a Rockwell " A " hardness of 92 (equivalent to 120 Scleroscope). Finish grinding is accomplished with diamond bonded wheels which impart an extremely brilliant and lustrous surface finish to the roll face. Profilometer tests indicate a surface variation of less than 0·0000006 in.

Solid carbide rolls, similar in design to steel rolls, are used for rolling strip wider than ¼ in. Nickel steel arbors with carbide sleeves are used for rolling flat or shape wire, metal tinsel and ribbon. Sleeve-type rolls are water cooled internally. The low thermal expansion properties of carbide rolls make it possible to roll flat and shape wire to tolerances of 0·0001 in.

Carbide rolls are used as either idle or driven rolls, the torsion strength being superior to carbon steels and only slightly inferior to alloy steels. Rolls in diameters up to 24 in. and lengths up to 40 in. can be produced with existing equipment, the largest weighing in excess of 1,000 lb.

Rolling speeds, amount of reduction, annealing cycle, roll shape and other operating procedure closely follows established practice with steel rolls with minor variations. However, speeds up to double normal practice can be used without affecting roll life. Reductions per pass from 10 to 20 per cent greater than standard can be taken with less power being required than with steel rolls. A 95,000,000 psi modulus of elasticity value, three times that of steel rolls, makes possible the production of bright finish strip having twice the flatness and smoothness of steel rolled strip. Only ¼ to ½ the normal amount of tin, copper or other plating material is required to plate carbide rolled steel. The edges of steel punches and dies last twice as long when stamping carbide rolled steel. The combination of a 750,000 psi compressive strength and extremely hard structure gives carbide rolls long life—outlasting steel rolls 50 times on low carbon steel and 25 times on hard alloys and stainless.

Extreme care is needed in installing carbide rolls to avoid misalinement. They should not be installed after taking initial passes with steel rolls. Best results are obtained using carbide rolls through entire rolling cycle. A rolling oil with more body and film strength is required because reduction is accomplished over a smaller area of contact as carbide rolls do not flatten out. On dry grinding, carbide rolls hold their polish 10 to 15 times longer than steel rolls.

No crown is required to compensate for deflection. Carbide rolls are occasionally hollow ground from 0·0002 to 0·002 in. Maintenance costs are less because they require fewer regrinds. Normally only 0·0005 in. is removed per grind compared to 0·002 in. for steel rolls. Rolling mill manufacturers are now building mills designed to accommodate carbide rolls.

SURFACE WAVES AND THEIR APPLICATION TO TRANSMISSION LINES.

The use of ordinary enamelled wire in place of coaxial cables or rigid wave guides for the transmission of ultra-high-frequency signals is forecast in a report now available from the Office of Technical Services of the U.S. Department of Commerce, Washington 25, D.C.

The novel UHF transmission means, developed by Dr. Georg Goubau for the Army Signal Corps, utilizes the hitherto unexploited principle that non-radiating cylindrical surface waves can be guided by a conductor that is coated with a dielectric layer, or the surface of which has been otherwise modified, for example, by being threaded.

According to the report, surface wave transmission lines, using special horn-shaped signal-launching devices, can be built to operate with lower loss than coaxial cables, or even than rigid wave guides.

The report is concerned with an investigation of surface waves on a conductor having a plain surface ; on a conductor having a modified surface, particularly a dielectric coating ; and the efficiency of a launching device for such waves.

Theoretical transmission losses are found to compare favourably with actual measured losses of experimental models.

The British Standards Institution has opened a branch office at 12 Hilton Street, Manchester, 1. (Telephone : Central 4856. Telegrams : Bristandin, Manchester).

At this office a complete set of British Standards, some 1,600 in number, may be consulted and copies purchased if desired.

Any information about the B.S.I. can be obtained by reference to Mr. A. F. B. Nall, an Assistant Technical Director of the Institution, who is in charge of the Manchester office.

REFRESHER COURSE FOR WORKS AND PLANT ENGINEERS

Following on the outstanding success of the Refresher Course for Works and Plant Engineers held at Bristol last winter, and of its replica now being held at Nottingham University, details are announced of a shortened version. This Course, for responsible engineering executives, will be conducted at the Plymouth and Devonport Technical College weekly on Thursday evenings for a period of eleven weeks, commencing on November 9th.

The Course has been organized by the Committee responsible for the original Bristol Course, under the Chairmanship of Mr. L. G. Northcroft, O.B.E., B.Sc. (Eng.), M.I.Mech.E., M.I.H.V.E., which includes the Regional Chairmen of the leading Engineering Institutions in collaboration with the Ministry of Fuel and Power and the Regional Advisory Council for Further Education.

The fee for the eleven weeks' course will be two guineas. Full details can be obtained from the Secretary to the Refresher Course, Plymouth and Devonport Technical College, Tavistock Road, Plymouth.

ELECTRICAL CONTROL GEAR

Simplification and standardization of types and then specialization by each manufacturer in one portion only of the range of products still required are among the recommendations of the Electrical Control and Switchgear Productivity Team in a Report, published by the Anglo-American Council on Productivity, on a visit to the U.S.A. The Team makes special reference to the extended use of direct started squirrel cage motors.

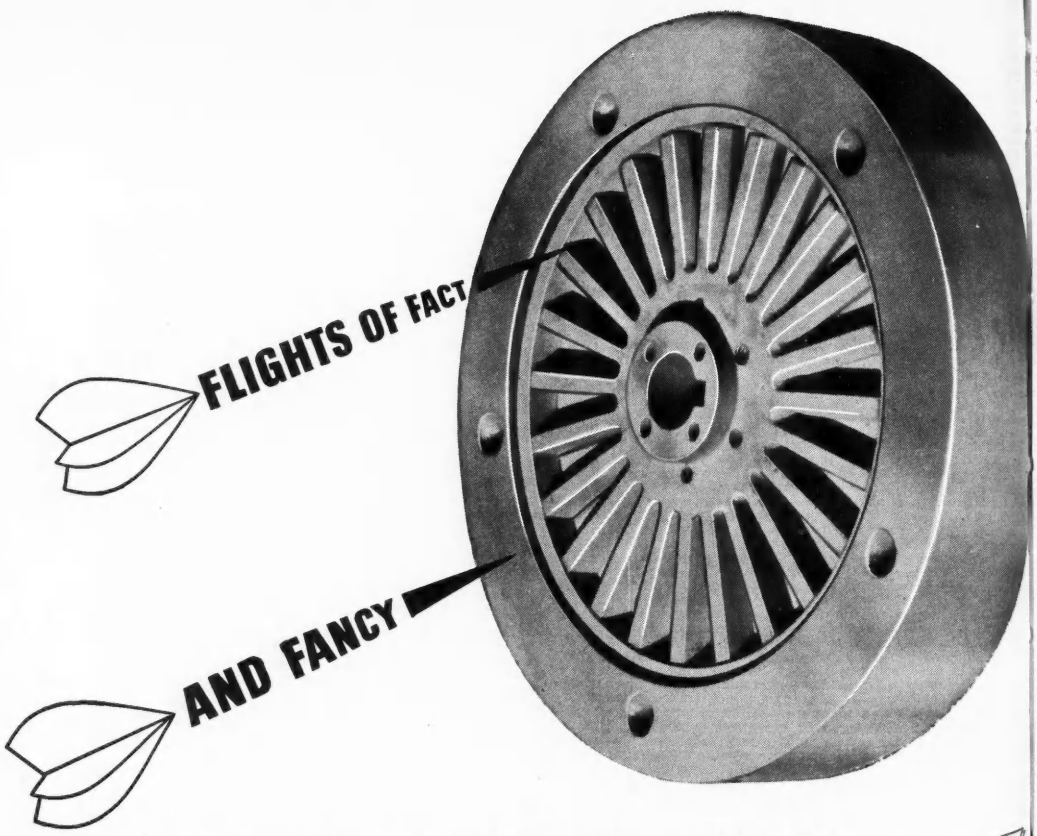
Other recommendations include the provision of power operated tools, the elimination of unnecessary handling by the arrangement of machines and processes, and the provision of mechanical assistance in order to reduce physical effort. The aggregate effect of detailed suggestions made in the Report will have a marked effect on the rate and the cost of production.

The Team was particularly interested in motor starters and control gear of the hand operated and automatic types for use with motors for industrial purposes from ¼ h.p. to 200 h.p. and in air-break switches of the types used for industrial purposes up to 400 volts, 300 amperes.

Though full application of the Report's recommendations would have a far-reaching effect on productivity the Team does not think that there is in Great Britain the same scope for mass production of control gear as in the U.S.

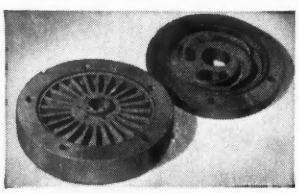
In Great Britain the population is only one third of that of the U.S., the electricity supply authority is not in a position to cope with a heavy demand for more power, and the direct switching of squirrel cage motors is not always regarded with favour for a variety of reasons, though not all of them are valid in the long run. The squirrel cage type of motor is held in high favour, but there seems far less objection in America to its being direct switched. As a consequence British manufacturers, with a smaller market, are asked to produce a much greater variety of control gear.

The outstanding lesson to be learned from the tour is that circumstances have enabled the American control gear industry to effect simplification and standardisation to a much greater degree than has been possible in this country. These circumstances include : Few restrictions by the electricity supply undertakings with regard to permissible switch-on currents of motors ; The attention paid by manufacturers to the production of squirrel cage motors with low switch-on currents ; The care taken by machinery makers and users to ensure the proper application of direct-started squirrel cage motors ; Recognition of the fact that when direct-started squirrel cage motors are used circuit protecting devices must be able to withstand the high starting current and that to make this practicable the usual requirements as to cable protection must be relaxed ; The much larger home market.



Not by any stretch of imagination would Tufnol make a good dart-board, yet our illustration, which is part of a chemical pump, serves a double purpose. It proves two points—the accuracy and intricacy possible in machining Tufnol and its resistance to corrosion.

But Tufnol combines many other qualities ideally sought after in metals and hardwoods but seldom realised in either. It is only half the weight of aluminium yet structurally strong enough to work sympathetically with steel; it is an excellent electrical insulator, yet it will not splinter or crack under impact. Neither exposure to corrosive atmospheres nor extremes of climatic conditions have any appreciable effect on its composition or finish. Given ordinary workshop facilities, any component can be easily produced from standard Tufnol sheets, tubes, rods, angles, or channels. Specially moulded blanks or finished parts can also be supplied to your exact specification. Can you afford to make-do without Tufnol when others are making progress with it?



An open view of a chemical pump made of Tufnol

CHALK THIS UP TO TUFNOL

You are welcome to apply for any or all of the handbooks containing useful data, particular uses, and in fact everything known about Tufnol. But what may be more important to you is our keenness to co-operate in any technical development incorporating its use in new ways. Why not outline your requirements in a letter —and send it TODAY.

TUFNOL

REGISTERED TRADE MARK

An ELLISON Product

TUFNOL LTD • PERRY BARR • BIRMINGHAM • 22B

In the U.S. owing to the great popularity of the direct-started squirrel cage motor the production of the direct-on magnetic starter far outstrips the sum of all other types. As a result, in the U.S. the magnetically operated contactor has reached a high stage of development and standardisation.

The Team does not suggest that it is practicable to eliminate all the alternative types of starters from the range of British manufactures. For one thing, there is a substantial export trade in some of them. Nor would it be economical for all starter makers to embark on mass production on American lines in view of the much smaller size of our home market.

As regards airbreak switchgear the designs and methods of production of switches and switchfuses did not appear to be superior to British.

Testing has received much attention in America and British Standard Specifications might well be reconsidered with a view to reduction in test expense.

As to labour, the Team saw many instances of high rates of production, both in machining and assembly. In no case did it appear to be the result of undue effort but rather of deftness, such as can only be attained if the basic design of the article lends itself to mass production, if an uninterrupted supply of good material is available, if the range of action demanded from each operator is limited and, finally, if jigs, fixtures and tools are efficient as to location, etc. and easy to manipulate. Judging by the results seen, the skill in the whole field of production planning in the U.S. is of a high order and plays a major part in the successful practice of mass production.

Where the job does not engender any sense of rhythm, but calls for conscientiousness, the Team does not consider that the American worker is superior to the British. Payment by results is practised in both countries. If here, as in the U.S., it was accompanied by an adequate supply of consumer goods at reasonable prices, the Team believes that the added incentive would be reflected in increased output.

Two chapters of the Report are devoted to a general survey of production in the U.S. and to a description of interesting machines, methods and designs observed during the tour. On the scale of mass production the Report gives the following figures as typical of the weekly rates of production in a number of the factories visited :

Magnetic starters	2,000
Pressure switches	7,500
Safety switches (switch fuses) ..	17,500
Domestic circuit breakers	37,000
Bus ducts	75,000-ft.
Push-button operated manual starters	4,800

In addition, float switches, push buttons and miniature snap action 2-way micro-gap type switches are made in large quantities. The demand appears to be sufficient to warrant this rate of production for a considerable part of the year.

The usual procedure with mass produced articles is to break the final product down as far as possible into sub-assemblies. Final assembly is done on a belt conveyor, the sub-assemblies being loaded at the beginning or fed in at points along the line. The necessary tests are applied along the assembly line, and very ingenious, not to say intricate, mechanisations for this purpose have been designed. " It is within our knowledge," the Team comments, " that at least one British firm is practising mass production methods which are as thorough as any seen in the U.S." With custom built gear a good deal has been done in the U.S. towards a measure of standardisation.

A large proportion of the apparatus seen was of first class quality in every respect, and several interesting features of design were noted. Most of the factories visited were well equipped for the mechanical handling of material at all stages of manufacture. In one factory with about 1,200 employees the foreman of the trucking department had a motor scooter to enable him to find his truck drivers quickly. Large personnel staffs are engaged and much time and trouble are taken in placing individuals in the types of job for which they are best suited. In all factories visited working conditions were of a high standard. There was better lighting, heating and draught-proofing than is usual in Britain.

The average worker's pay for a 40-hour week was given as 60 dollars, the hourly rate ranging from 80 cents to 2 dollars for highly skilled workers such as tool makers.

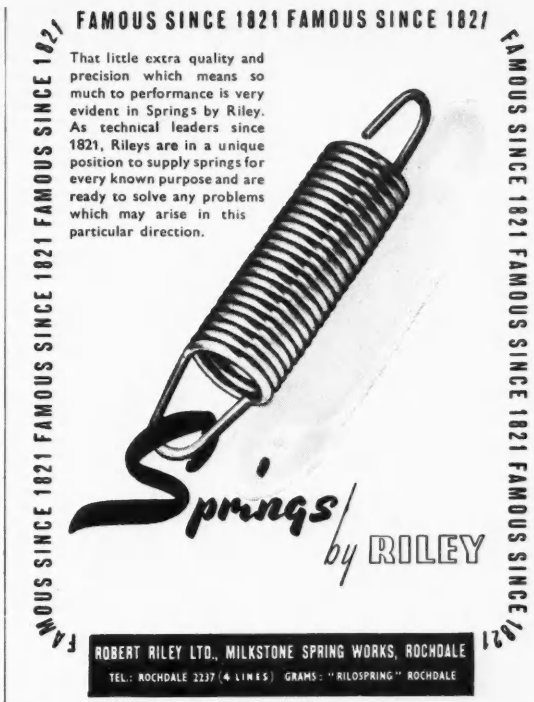
A chapter of the Report describes business and office methods. Tables and graphs give the relative cost in hours of work in London and New York, not only of common articles of consumption but also of electrical control gear. In comparison of the " labour content " time of standard products the Team concludes that on the smaller sizes, within the range of horse powers where direct switching is the most common form of starting in Britain as well as in the U.S., the labour times are not dissimilar.

Copies of the Report, price 2/-, post free, may be obtained from the Anglo-American Council on Productivity, 21 Tothill Street, S.W.1, and the British Electrical and Allied Manufacturers Association, 36 and 38, Kingsway, London, W.C.2.

A Mach Number Chart, recently prepared by the Square D Company's Kollsman Instrument Division for the convenience of its staff engineers, is now being offered free of charge to the engineering departments of organizations in aviation and allied fields.

The chart gives the standard values for measurement of high speeds in terms of Mach number, indicated air speed, differential pressure, altitude and absolute pressure. Pressure ratios, differential pressures and stagnation pressures for various Mach numbers are provided in tabular form.

The Kollsman Mach Number Chart may be obtained from the Square D Company's Kollsman Instrument Division, 80-08 45th Avenue, Elmhurst, New York.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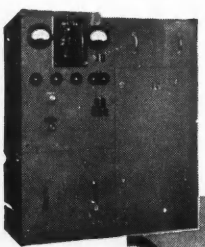

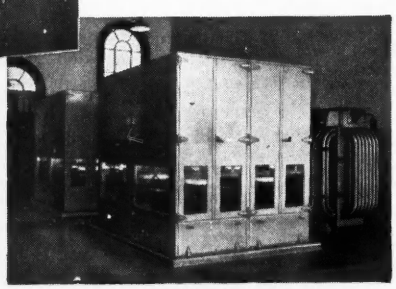

35 kW.—*(inset) Hewittic rectifier operating a rubber calender, providing an extremely wide range of speed variation by means of grid control.*

500 kW.—*(right) Hewittic rectifier installation supplying D.C. to motor-driven plant at a gasworks.*

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BRITISH STANDARDS

(Copies of British Standards may be obtained from the British Standards Institution, 24, Victoria Street, London, S.W.1)

Steel Tubes for Automobile Purposes (B.S. 980 : 1950). Three types of steel tube are covered—cold drawn seamless, electric resistance butt-welded, and cold drawn electric resistance butt-welded. Within each type, a number of grades are specified. In the case of cold drawn seamless tubes, the range extends from soft mild steel to high tensile and stainless steel.

Mechanical properties and chemical composition are laid down for each grade of tube. For butt-welded tubes, provision is made for an hydraulic test if required. Dimensional tolerances, including straightness, are specified.

A table at the end of the standard gives a useful summary of the chemical compositions and mechanical properties of the complete range of tubes. Price 2/6.

British Standards for the Automobile Industry. (B.S. Handbook No. 8 : 1950). The number of standards which are of interest to the Motor Industry is so large that it would not be possible to reproduce them all in full in one volume, but an endeavour has been made to compress into one cover of reasonable dimensions sufficient of the current British Standards, in extract, precis or list form, together with full details of S.M.M. & T. standards and extracts from American standards in popular use in Great Britain.

It is anticipated that this will enable designers and engineers to maintain an up-to-date knowledge of the standards which are of direct application in their work.

More than 300 standards are covered, including American S.A.E. standards, horsepower correction charts, ferrous and non-ferrous metals, bars and forgings, castings, sheet, strip, tubes and wire. Radio interference suppression is extensively dealt with and this Handbook should prove invaluable to those associated with the manufacture and servicing of automobiles, motor launches and associated equipment. Price 21/-.

Glossary of Aeronautical Terms. (B.S. 185, Part 1 : 1950). In view of rapid developments in aeronautics during recent years, a comprehensive revision of the 1940 edition of this Glossary became necessary, and is being issued in three parts, of which Part 2, devoted to power plant including jet propulsion equipment, propellers and auxiliary services was published in advance of Part 1 on account of its greater urgency. The part now issued contains definitions of symbols used in aeronautics and aerodynamics etc. generally, structure and movement of aircraft and specialized terms relating to heavier-than-air aircraft including rotorcraft, and lighter-than-air aircraft. An Appendix is devoted to aerodynamic symbols. Such subjects as parachutes, navigation, radio communication, ground organization and meteorology will be dealt with in Part 3. Price 7/6.

Graphical Symbols for Power Generating Plant. (B.S. No. 1553, Part II : 1950). This part of the standard for Graphical symbols for general engineering relates to power generating plant comprising boilers, steam and internal combustion engines and turbines, and auxiliary plant, including condensers, pumps, fans, tanks, de-aerators etc., with examples of diagrams showing the use of symbols. Price 2/6.

Graphical Symbols for Compressing Plant. (B.S. 1553, Part III : 1950). This part of the standard for Graphical symbols for general engineering relates to the specialized field of compressing plant, including applications to air-operated switch gear, and covers compressors and auxiliary plant such as coolers, dryers and receivers, with examples of diagrams showing the use of the symbols. Price 2/-.

Machine Tapers. (B.S. 1660, Part I : 1950). The first part of this Standard has now been issued and deals with self-holding tapers and gauges for self-holding tapers. It establishes a simplified series of self-holding tapers by a selection of those sizes from the Metric, Brown and Sharpe and Morse series which are most commonly in use and which at the same time provide a standard series having approximately uniform increments in sizes.

Dimensions and tolerances are given for three types of shank and their appropriate sockets and it should be noted that whilst the shanks are described as self-holding, they are also, in fact, self-driving, since the tang, where present, is intended for ejection purposes only. Dimensions and tolerances and certain general requirements for several types of plug and ring gauges are included, and a recommended method of checking the wear of gauges is given in an Appendix.

Shanks and sockets made to this Standard are interchangeable with those made according to existing practice, and it is strongly recommended that one of these Standard tapers be adopted for every new design of tool in order that the inconvenience and uneconomic production which have in the past resulted from an unnecessary multiplicity of tapers may be avoided in the future.

Further parts of the Standard now in course of preparation will relate to tapers with cotter drives, self-releasing tapers and large machine tapers. It is also hoped to provide an Appendix to the Standard listing all available data on non-standard tapers. Price 5/-.

Steel Balls for Brinell Hardness Testing. (B.S. 240, Pt. 2 : 1950). This revision largely affects the hardness numbers set out in the tables dealing with the two different methods specified. The new numbers have been calculated from a more accurate formula, and a number of errors and inconsistencies discovered in the original have been corrected. Price 2/-.

Buttress Screw Threads. (B.S. 1657 : 1950). The buttress form of thread has certain advantages in applications involving exceptionally high stresses in one direction only, along the thread axis. As the thrust side of the thread is made very nearly perpendicular to the thread axis, the radial component of the thrust is reduced to a minimum and a solid bearing between the mating threads is produced. On account of this small radial thrust the

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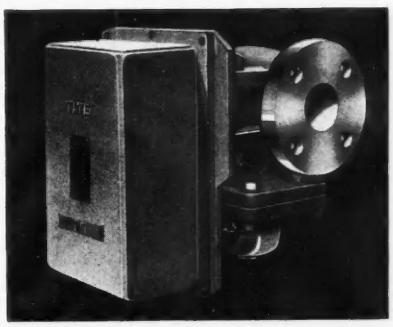

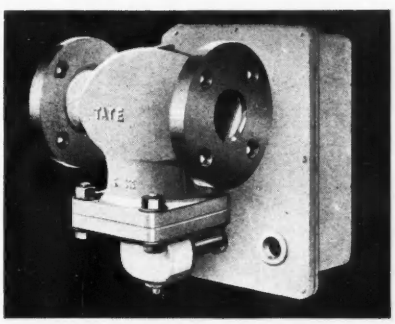

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buttress form of thread is particularly suitable when tubular members are screwed together. Examples of actual applications are the breech mechanisms of large guns, aeroplane propeller hubs and columns for hydraulic presses.

This standard provides for two forms of thread, designated respectively " Standard " and " Special " forms.

The " Standard " form of thread has a pressure flank angle of 7° with an included angle between the pressure and trailing flanks of 52°. In selecting the form of the standard thread, manufacture by the thread milling or grinding processes has been taken into consideration.

The " Special " form has the pressure flank normal to the axis of the screw with an included angle between the pressure and trailing flanks of 52°. This special form is unsuitable for manufacture by thread milling or grinding, but may be required to meet certain special requirements, as for example, applications in high pressure steam work involving differential expansions of the mating threads in which the provision of a 7° pressure flank might give rise to high bursting stresses.

As the use of buttress threads is confined mainly to specially designed components, no attempt has been made in the standard to introduce a rigid pitch/diameter relationship, but the standard does include preferred series for both diameters and for pitches.

Tables of tolerances and allowances are provided for three classes of fit, namely close, medium and free.

A recommended system of gauging is included, with notes on the appropriate types and design sizes of the gauges. An explanation is also given of the method of measurement of the effective diameter of buttress threads together with tables of dimensions for the best sizes of thread measuring cylinders. Price 3/-.

Industrial Perforated Plates. (B.S. 1669 : 1950) has been designed to cover industrial perforated plate having round and square apertures with the sizes and arrangements which are most commonly used, and tolerances on aperture size and pitch of apertures have been introduced.

No attempt has been made to standardize other shapes of aperture such as slots. The main reason for this omission is that a very wide range of these different shapes of aperture is involved. The bulk of industrial requirements, is, however, covered by B.S. 1669. The standard, in addition, contains three tables giving aperture sizes and three pitch arrangements for industrial perforated plate with apertures from ⅛ in. to 3 in. Price 2/-.

ELECTRODEPOSITION OF METAL POWDERS

(*Concluded from page* 358)

30° C, pH 1 and 40 A/dm². The black sponge formation observed at this temperature was completely absent under the same conditions, but at 90° C.

Thus, black spongy cadmium deposits may be formed under two substantially different conditions of electrolysis, viz. :

1. In acid solution at *high* current density and *low* temperature.
2. In neutral solution at *low* current density and *high* temperature.

G. OTHER THEORIES OF SPONGE FORMATION.

The view has been advanced by Russian authors that secondary oxidation at the cathode is responsible for the formation of powdery and spongy deposits [15, 16]. X-ray investigations revealed the presence of the lower oxides of the metals in the deposits.

The theory developed on the basis of these experiments postulates a secondary oxidation at the cathode, mainly by the anions, but also by the solvent and the atmospheric oxygen. Powdery or spongy deposits are said to be formed at low or very high current densities. The varying amount of oxides in the deposits is interpreted in terms of the oxidising power of the anions and the oxidisability of the metals.

In later work in the U.S.S.R. on the deposition of Pb, Cd and Zn at high current density[17], results were obtained which were contrary to expectations based on the oxidation theory. The author also rejects this theory, as the results on which it is based are easily explained in terms of depletion and hydroxide formation as developed above. The oxidisability of the metals is certainly of importance in their secondary oxidation, but their position in the electrochemical series also has some influence on the readiness with which hydrogen is co-deposited and the consequent formation of hydroxide in the cathode film. The oxidising power of the anions is probably best accounted for by noting its influence on the hydrogen overvoltage, causing depolarisation if they are reduced.

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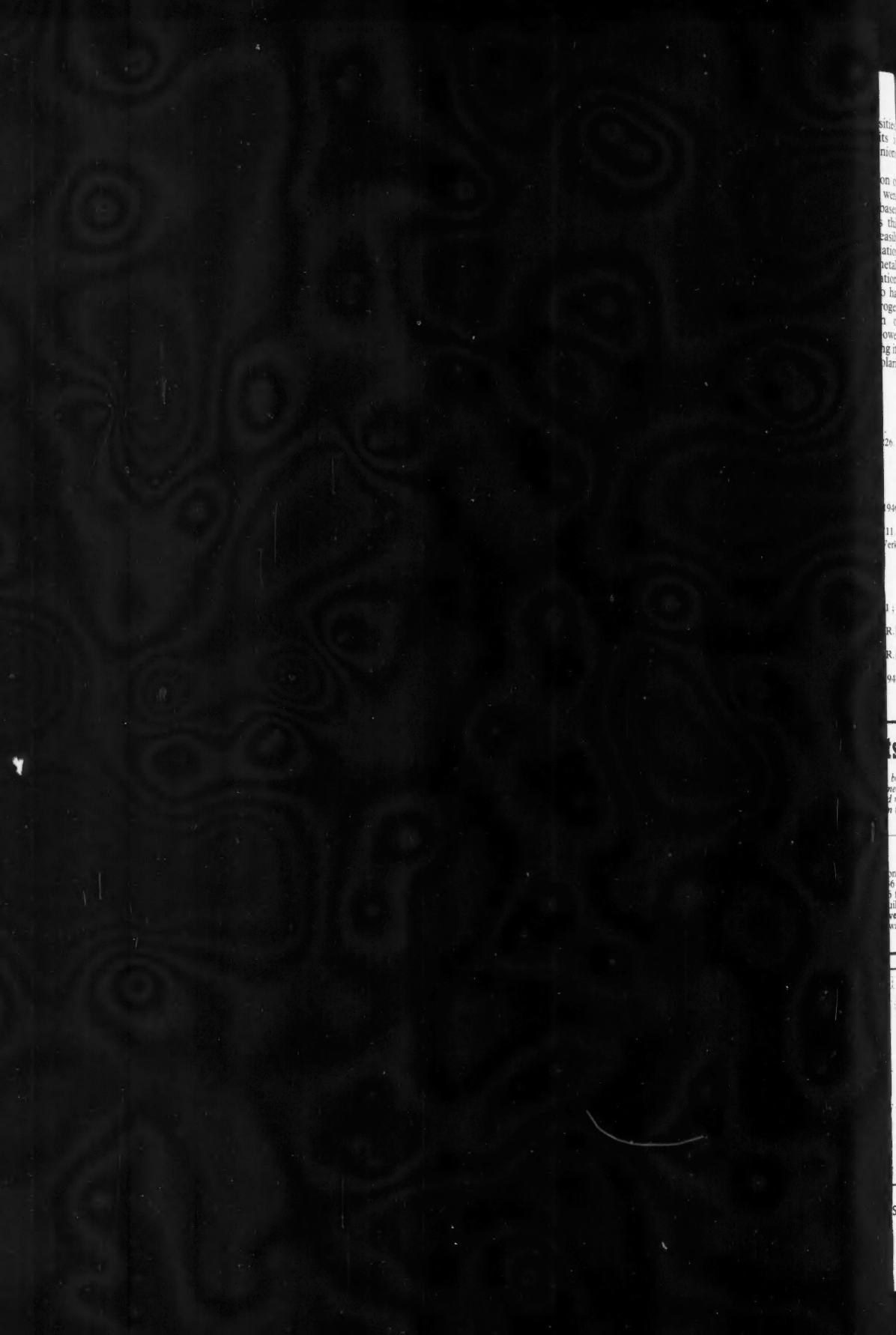

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A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *EFFICIENCY OF PLANETARY GEARS*

Increased attention is now being paid to the development of planetary gear drives for a wide range of applications, including high-power marine propulsion plant. In order to be able to estimate the performance characteristics of the various types of planetary gear trains available, data on relative efficiencies are required. In view of the great number of gear arrangements possible, actual operating data are not available for this purpose, and a theoretical yardstick for determining relative gear efficiency must be used instead. A recent theoretical investigation makes use of a simple mathematical expression for gear efficiency embodying empirical coefficients and being applicable to both external and internal gearing. In view of the relatively low mechanical power losses in the bearings, these losses may be neglected in a study of this type, it is claimed. The investigations referred to extend to seventeen different planetary gear trains, and their wide range enables the author to draw a number of general conclusions. One of these is that tooth friction losses of planetary gears are affected by the gear ratio to a far greater extent than is the case with ordinary gear trains. Planetary gears of high speed ratio are particularly vulnerable in this respect, but by appropriate design measures the efficiency of gears with high speed reduction ratio can be kept within tolerable limits. In the case of composite gears, overall efficiency may be considerably affected by the relative speed reductions chosen for the component gear trains.

● *MOLYBDENUM AS HIGH-TEMPERATURE MATERIAL*

The outstanding feature which makes molybdenum especially attractive for high-temperature applications is its high-temperature strength, the yield strength at 1800° F being some 40,000 psi under short-time test. A survey made in connection with a project for the utilisation of nuclear energy for aircraft propulsion reveals that massive pieces of molybdenum weighing up to 1,000 lb can now be produced by pressing and sintering. It is expected that molybdenum ingots of this weight produced by casting will also be available shortly. Considerable problems are encountered in the forging of large pieces, but experience is fast accumulating to ensure a product that is free from cracks and ductile enough for further fabrication. Much importance therefore attaches to a recent investigation concerned with improving the ductility of cast molybdenum by heat treatment in a vacuum at 2,100° F. The chief deterrent to its use, however, at the present time, is the lack of a satisfactory method for protecting the surface of the metal against oxidation when oxidising conditions exist at 800° F and higher. Some success has been obtained with an Inconel coating applied by roll bonding technique. A specimen has been held at 2,000° F for more than 400 hours and the test is still in progress. Molybdenum disilicide coatings have also proved successful in several cases.

● *HIGH-CAPACITY POWER FUSE*

In order to meet requirements for a fuse of high rupturing capacity in industrial and shipboard circuits, American engineers have developed power fuses with ratings of up to 100,000 r.m.s. amperes of a design based upon British practice. The tube of the fuse is made of a glass-cloth resin-impregnated material, and the filler is a specially graded quartz material originally developed for high-voltage power fuses. Subdivision of the active element required for a given ampere rating into a number of spaced parallel paths is adopted because it was found to assist in limiting transient pressure in the cartridge and thereby in increasing interrupting capacity. With regard to the melting characteristics of the element material, advantage is taken of the so-called "M-effect" described by A. W. Metcalf in a British publication in 1939. This is a metallurgical effect produced by the time-dependent alloying action taking place between the silver of the active element and small globules of a tin-rich alloy, lowering the melting point of the element in the low-current long-time region, but not coming into play in the high-current short-time region.

● *CHILLING FOR MILL GRINDING*

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hopper of the grinding mill and excludes atmospheric air, which would tend to raise the temperature of the system. This low-temperature cooling produces a highly brittle condition of the material, so that the amount of energy required for grinding is greatly reduced. The new process promises to accelerate the high-speed pulverisation of mechanically tough or heat-sensitive materials, such as plastics, pharmaceuticals, insecticides, foodstuffs, substances containing vitamins and other organic materials. Saran and polystyrene, for instance, are being successfully pulverised by this method on a production scale. Inherent advantages of the use of liquid nitrogen are that, being a liquid, its cooling action is more rapid than that of solid refrigerants and, as it is chemically inert, it can be used in direct contact with the material to be pulverised. The importance of an inert atmosphere in the grinding of explosive or oxidisable materials need hardly be stressed. At the present time, application of the process is limited to materials which are able to absorb the increased processing cost.

● *MILL ROLL BLASTING*

Rolls roughened to varying degrees of etch are used in temper mills to impart the special surface treatment required for certain cold-rolled products, such as tin plate. They are also used to prevent slippage in cold-rolling and to provide special surfaces for deep cold-drawing operations, galvanizing, vitreous enamelling, painting, etc. Roll blasting is effected by an airless method, in which the abrasive is thrown against the roll by centrifugal force. Since the introduction of this method in 1933, many improvements have been effected in roll blasting technique. A representative installation incorporating the latest features is designed to handle rolls for a tin mill, the roll diameters ranging from 15 to 20½ inches with 42 to 54-inch working faces and overall lengths from 9 to 12 feet. Provision is made to obtain coarse, medium, or fine finish on the rolls by the use of three sizes of chilled iron grit abrasive and by automatic control of the roll movement during treatment. Blasting is effected by a standard airless unit of the aforementioned centrifugal type, its wheel throwing a maximum of 400 pounds of abrasive per minute. The roll to be treated rests on a work car, which spins and moves the roll under the wheel blast so as to ensure uniform roughening.

● *HIGH-ALTITUDE ELECTRONIC ANEMOMETER*

A special radio technique of analysing the drift of meteor trails to measure wind velocities and directions in the ionosphere at altitudes of 55 to 80 miles has been devised. This method is based on the fact that the passage of meteors through the outer atmosphere produces electrical disturbances, which act as efficient reflectors of radio waves and may be detected by a radar-like technique. Each disturbance lasts only a second or so, but during that time it drifts like a puff of smoke under the influence of outer atmosphere winds. In order to obtain readings of reasonable accuracy with such an electronic anemometer, a considerable number of such meteor echoes is required, but due to the fact that large numbers of minute particles of meteoric dust incessantly enter the earth's atmosphere, this method is potentially capable of even producing a continuous record of wind velocities. Knowledge of high-altitude winds renders information on the composition of the upper air, and this information is valuable to high-altitude aircraft designers in connection with aerofoil design.

● *COMMUTATORLESS DIRECT CURRENT GENERATION*

An interesting proposal for the commutatorless generation of direct current concerns a fluid machine which uses an electrolytic liquid or gas flowing in a magnetic field. A working model using mercury, which is designed to work as a motor, consists of a U-tube, the upper ends of which are connected to a reservoir. Four pairs of electrodes connected in series are used: two on each leg of the U-tube. When the tube is filled with a conducting fluid, such as mercury, and a potential is imposed on the electrodes, the mercury in the tube completes the circuits and current flows. If the system is now placed in a magnetic field, with the flux perpendicular to the U-tube, the circuit current cuts the magnetic field and a pressure develops in the mercury, causing it to flow. Mercury pumps embodying this principle are, of course, not novel. However, a system of this type can also be used to operate as a generator by pumping the mercury through the system. It should therefore be possible to develop a commutatorless generator capable of generating considerable voltages. By using mercury vapour flowing at a velocity of 1,000 fps, through a magnetic field strength of 12,000 gauss, between electrodes 10 inches apart, a potential of 100 volts would be developed per pass.

● *INCREASING FATIGUE STRENGTH OF STAINLESS STEELS*

A special nitriding process has been developed for the surface-hardening of both the austenitic and the ferritic stainless steels. These steels cannot be successfully nitrided by the conventional nitriding process because of the chemically inert film of chromium on the surface of the work. It is necessary to reduce this film by means of nascent hydrogen before the surface of the material will combine with nitrogen. There are many applications of stainless steels where the component in question is subjected to repeated full or partial stress reversals. Unfortunately, neither the austenitic nor the straight chromium stainless materials

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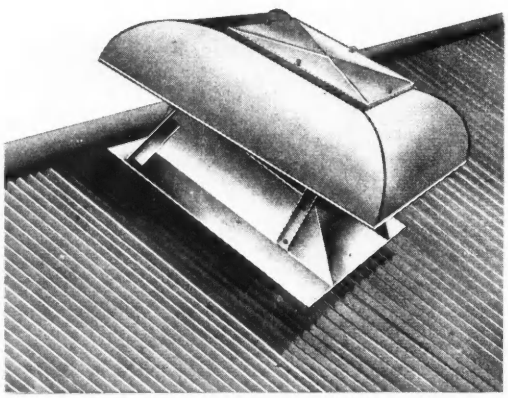

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*The illustration shows a General Purpose Furnace for tool-room and production. Temperatures up to 1050°C.

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have particularly high fatigue strength, especially in the notched conditions. Nitriding the stainless steel is the most satisfactory means of increasing fatigue strength without materially sacrificing the other desirable properties of the base material. This increase in fatigue strength s attributed to the compressively stressed case on the surface of the piece. Generally speaking, surface hardening may increase the fatigue strength of unnotched 12 per cent chromium material by 15 per cent. A corresponding increase in fatigue strength of 30 per cent may be obtained for a material of the 18 per cent chromium-18 per cent nickel type. The fatigue strength of notched material of the 12 per cent chromium type may be increased by 750 per cent by surface-hardening.

● *NEW ELECTROLYTIC IRON POWDER*

A new electrolytically produced iron powder for purposes of powder metallurgy is now being manufactured on a pilot plant scale. This powdered iron physically resembles Swedish sponge iron, but has the purity of the best electrolytic iron powder, there being no residual unreduced oxides as in the sponge process. It is also claimed that due to the dendritic structure in which the powder is obtained, compacts are more easily made. The dendritic structure causes interlocking of the particles at usual working pressures, while the softness of the iron itself permits the forming of a dense compact upon increasing the pressure. Sintering temperatures seem to be somewhat lower; temperatures approximating to 1300° F are reported to produce good results as compared with 1500 to 1800° F commonly used. Electrical properties are improved insofar as powdered iron cores show lower hysteresis and eddy current losses, owing to the lower density of the compact when produced for core purposes. The powder is produced from ordinary cast iron or mild steel scrap in the form of chips or turnings placed in a chemical bath in iron trays serving as anode. The iron is dissolved and deposited from the solution in a mercury cathode, which becomes impregnated with the iron. The iron is then recovered as fine particles by distillation of the cathode, soft pulverising, and air classification.

● *GAS TURBINE OPERATION ON HEAVY FUEL OIL*

Open-cycle gas turbines have successfully operated on high-grade distillate petroleum fuels. To make gas turbine operation an economically attractive proposition, however, it is most important that gas turbines should be adapted to the use of the cheaper residual petroleum oils. Unfortunately, it has been found that these lower-grade fuels tend to produce heavy deposits on the turbine blading and are also highly corrosive. The metallic salts and other impurities responsible for this difficulty appear in the products of combustion as vapours, which condense upon and adhere to the turbine blading at the stage of the expansion process where the gas temperature has fallen to the dewpoint of these vapours. A recent invention envisages the use of a gas cleaning device to be passed by the combustion gases before entering the gas turbine. In this separating plant, the combustion gases are to be cooled from a temperature just above the dewpoint to a temperature just below it, so that the harmful vapours are condensed and can be removed. Furthermore, it is claimed that the introduction of a spray of sea water into the separating chamber promotes the deposition of vanadium pentoxide by catalytic action. Bearing in mind the considerable trouble caused by this constituent, practical developments of this process will be watched with great interest.

● *ELECTROPLATING OF ALUMINIUM DIE CASTINGS*

The electroplating of aluminium has long been a problem because this metal does not respond satisfactorily to the usual procedures employed to prepare other metals for plating. This is due to the fact that the alloying metals in aluminium take several forms, the surfaces of which do not respond uniformly to the various chemical and electrochemical treatments. Another source of trouble is the ever-present natural oxide film, which cannot be completely removed but must be made thinner and more uniform. Several procedures for the electroplating of aluminium have been recommended, and good results are reported to have been obtained with their use. Standard procedure involves a zinc immersion coating as a preliminary to electrodeposition. In this method, the casting is immersed in a highly alkaline proprietary solution of sodium zincate. The oxide film is removed from the aluminium surface to be plated and is replaced by a thin and adherent layer of metallic zinc. This provides a surface that will respond to most of the plating procedures for depositing other metals. Another process includes a double zinc immersion treatment, in which the first zinc layer is removed by a nitric acid dip and replaced by a second and more easily plated layer. Although chromium and other metals can be plated directly on the zinc immersion layer, it is ordinarily advisable to use a Rochelle-type copper cyanide solution to apply a thin copper layer. This is then followed by a nickel layer and finally by the chromium layer.

● *INITIAL BOLT STRESSES*

In highly stressed bolted connections, it is important to know the magnitude of the initial stresses produced by tightening before external load is applied. It is obvious that the initial stress should neither be too high for reasons of mechanical strength nor too low in consideration of joint tightness or rigidity. Direct measurement

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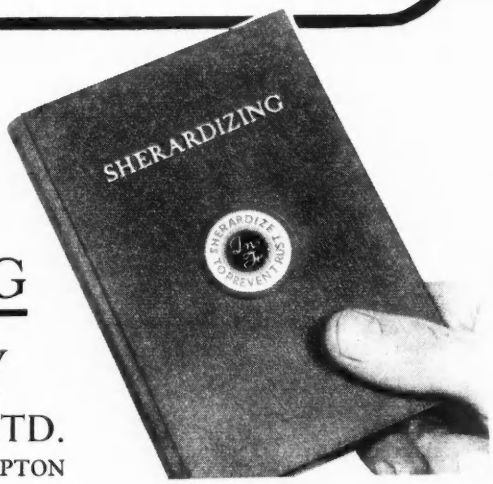

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of bolt stress when screwing-up tight is difficult, and where danger of overstressing exists it is usual to limit initial tensile bolt loading by using torque wrenches or spanners equipped for dial indication of the torque applied. It is easily seen that these methods cannot take account of the influence of varying thread friction. Where more accurate knowledge of the initial bolt tension is required, direct measurement of the bolt elongation due to tightening is required. More often than not, direct external measurement of the elongation will not be possible, and in the case of studs it is, of course, altogether impossible. A simple but effective solution to the problem is available in cases where the bolt or stud may be provided with a central bore sufficiently large to permit insertion of the feeler of a dial gauge, which affords direct indication of the elongation. An instrument of this kind, suitable for bolts up to five inches long, has been subjected to exhaustive trials, which, it is reported, have proved its accuracy and general utility.

● *LONG-TIME CORROSION TESTING OF CAST IRON*

In spite of the great amount of research conducted in recent years into the corrosive influence of aqueous solutions upon the various metals and their alloys, knowledge of the subject is still scanty both as regards theory and empirical data. Especially unsatisfactory in this respect is the situation in the case of cast iron. This is, of course, partly due to the inhomogeneous structure of cast iron, caused by the presence of uncombined graphite. The special position occupied by cast iron with regard to corrosion problems is emphasized by the observation that the application of static loading produces an electric potential difference between the metallic structure and the graphite which increases with the stress. This phenomenon is even more pronounced if the material is subjected to dynamic stresses. Long-time tests, in which cast iron bars immersed in sea water were subjected to bending stresses over periods as long as 10,000 hours, have yielded important information, and their value is further enhanced by the feature that parallel tests were conducted in air at room temperature. These tests, which were made at various stresses, have shown that cast iron is liable to creep both in air and in sea water, but that the attendant corrosion in sea water considerably shortens the time up to failure by rupture.

● *NEW BRITTLE LACQUER FOR STRESS ANALYSIS*

In spite of its apparent simplicity, the employment of brittle lacquers for the purpose of stress analysis is still somewhat hampered by the considerable experience and care required in its application. There is, however, little doubt regarding the usefulness of this method for ascertaining the location of stress concentrations. Greater familiarity with the technique of its application may, therefore, result in the use of this method on a larger scale. In addition to ordinary plumber's resin, proprietary brittle lacquers are available, and reports on results obtained with their employment have been published from time to time. Improved characteristics are claimed for a new product of this kind, which is sprayed in a thin layer upon the surface to be examined and then flame-dried to form a uniform film enabling the exact location of maximum stress to be determined. Approximate assessment of the magnitude of the stress can also be made, it is claimed. An interesting feature of the new method is the utilisation of an electrolytic process to improve the visibility of the minute fissures produced in the lacquer film. The original report from which this information was gleaned gives full instructions regarding the application of what appears to be a very simple and rapid electrolytic treatment producing the desired effect.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.

● *TANTALUM ELECTROLYTIC CAPACITORS*

In miniaturised equipment, it is frequently necessary to provide capacitance of the order of several microfarads in a very small space. It appears that by the recent introduction of tantalum as electrode material, an electrolytic capacitor type has been created, which is superior to the aluminium foil type both as regards space requirement and service reliability. Tantalum has both chemical and mechanical advantages. From a chemical standpoint tantalum resists attack from most acid reagents and permits the use of electrolytes with operating characteristics superior to those which can be used with aluminium. In mechanical respects, tantalum permits fabrication in smaller size than is possible with aluminium. Tantalum capacitors are made in either the conventional foil construction or in the sintered type. As tantalum foil is rougher than aluminium foil, it provides 10 to 20 per cent more effective area. Moreover, its oxide film has a 50 per cent higher dielectric constant, and the metal can be used in thinner form. Thus, foil-type tantalum capacitors are about 30 per cent smaller than etched aluminium foil capacitors. In the sintered type, the anode is made by pressing powdered tantalum into a compact and then sintering it. As electrolyte, an aqueous solution of lithium chloride is used; the safe operating potential of the sintered type is 70 volts as compared with 150 volts for the foil type.

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